MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

EXPLANATION OF SHEET 142.

THE GEOLOGY OF THE MELTON MOWBRAY DISTRICT AND SOUTH-EAST NOTTINGHAMSHIRE.

BY

G. W. LAMPLUGH, F.R.S.; W. GIBSON, D.Sc.; C. B. WEDD, B.A.; R. L. SHERLOCK, B.Sc., AND B. SMITH, M.A.

WITH NOTES BY C. FOX-STRANGWAYS, F.G.S.

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Sheet 11, which includes large parts of Derbyshire, Nottinghamshire, Cheshire, Staffordshire, Leicestershire, Rutland and Lincolnshire is in course of preparation.

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Sheet 110 (Macclesfield, Crewe, &c.) 1906; Explanatory Memoir, price 2*s.* 6*d.* (1906).

Sheet 123 (Stoke-upon-Trent) 1906; Explanatory Memoir (2nd Edition), price 1*s.* 6*d.* (1905).

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Sheet 141 (Derby, Loughborough, &c.) 1905; Explanatory Memoir, price 2*s.* (1905).

Sheet 142 (Melton Mowbray) 1909; Explanatory Memoir.

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Sheet 155 (Solid or Drift) and Sheet 156 (Solid) are obtainable at present in the hand-coloured form only.

IRONSTONE WORKING ½ MILE WNW. OF WARTNABY.

Boulder Clay overlying an uneven and glaciated surface of Middle Lias Marlstone (*see* pp. 48 and 70).

MEMOIRS OF THE GEOLOGICAL SURVEY.

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PREFACE.

The original geological survey of the area was made on the Old Series one-inch map ; the north-western part, on Sheet 71 S.E. having been surveyed by Edward Hull ; the south-western part, on Sheet 63 N.E. by H. H. Howell ; the north-eastern part, on Sheet 70 by W. H. Holloway, A. J. Jukes-Browne and W. H. Dalton ; and the south-western part on Sheet 64 by J. W. Judd.

The recent re-survey on the 6-inch scale, on which the new map is based, was begun by Mr. C. Fox-Strangways before his retirement in 1904, and was completed in 1906 under the superintendence of Mr. G. W. Lamplugh, who has also acted as editor to the present Memoir. The names of the various officers engaged on the work and the areas for which they are severally responsible are recorded on page iv.

The memoir describes the geology as depicted on Sheet 142 of the New Series Colour-printed One-inch Map. The map is published in a Drift edition only, but the continuation of the boundaries of the 'Solid' rocks, where concealed by Drift, is shown by engraved lines.

The western half of the new one-inch map differs in some important particulars from the corresponding portions of the earlier maps on the same scale. The boulder-clay which attains a great thickness over an extensive tract of country in the area in question and the Rhætic beds are now represented for the first time.

The oldest rocks actually exposed at the surface belong to the Trias, but the presence of deep-seated Coal Measures has been ascertained by borings in the north-western part of the area, as described by Dr. Gibson in Chapter II. The commercial value of the extension of the Nottinghamshire Coal-field into the area represented by this sheet remains to be proved. At present the principal mineral products of economic consequence in the district are the iron-ores of the Middle Lias, the cement-stones of the Lower Lias, and the gypsum of the Keuper formation. The extensive workings for these minerals are described in subsequent chapters. We have received much assistance from the firms engaged in all these industries and desire to express our appreciation of their courteous help.

J. J. H. TEALL,
Director.

Geological Survey Office,
28, Jermyn Street, London,
17th August, 1909.

(12262—17.) Wt. 28120 500. 10/09. D & S.

LIST OF SIX-INCH MAPS.

The following is a list of the six-inch Geological Maps included in the area, of which MS. coloured copies are deposited for public reference in the Library of the Geological Survey and Museum of Practical Geology :—

NOTTINGHAMSHIRE.

QUARTER-SHEETS.

46 NE., NW., SE., SW., by R. L. Sherlock.

47 NE., NW., SW., by B. Smith.

47 SE. (= LEICESTERSHIRE 6 SE.), by B. Smith.

50 NE., NW., by R. L. Sherlock.

50 SE., SW. (= LEICESTERSHIRE 11 SE., SW.), by R. L. Sherlock.

51 NW., SW. (= LEICESTERSHIRE 12 NW., SW.), by B. Smith.

also small portions of—

42 SE., SW., by R. L. Sherlock.

43 SE., SW., by W. B. Wright.

LEICESTERSHIRE.

7 NE., NW., SE., SW., by W. Gibson.

12 NE., SE. (= NOTTINGHAMSHIRE 51 NE., SE.), by G. W. Lamplugh.

13 NE., NW., SE., SW., by C. B. Wedd.

18 NE., NW., SE., SW., by C. Fox-Strangways.

19 NE., NW., SE., SW., by C. Fox-Strangways.

20 NE., NW., SE., SW., by C. B. Wedd.

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THE GEOLOGY OF THE MELTON MOWBRAY DISTRICT AND SOUTH-EAST NOTTINGHAMSHIRE.

CHAPTER I.

GENERAL DESCRIPTION.[1]

Introduction.

The area of the map (New Series, Sheet 142) described in this memoir is shown on a reduced scale in the index-map on the next page (Fig. 1), which will suffice to indicate its limits. In the Old Series maps of the one-inch scale on which the previous Survey was carried out, the greater part of the area fell within the quarter-sheet 71 SE. (published in 1855, with additions in 1879), and smaller portions within the ¼ sheet 63 NE. (1855, additions 1873), and the whole sheets 64 (1872) and 70 (1886). For the two sheets last-mentioned there were separate 'drift' editions, in which the glacial deposits were shown; but the old ¼ sheets 63 NE. and 71 SE. represented the 'solid' geology only, there having been no mapping of the drifts in most of the area of the present sheet. The recent survey was carried out on field-maps of the six-inch to the mile scale, from which the reduction was made to the one-inch scale, now published. Copies of the original six-inch maps, of which a list is given on p. iv, are available for public reference at the Library of the Geological Survey and Museum, Jermyn Street, London.

The field-work in the south-western part of the map, as far north as Stanford-upon-Soar and eastward to Kirby Bellars, was done by Mr. C. Fox-Strangways before 1901; the rest of the ground was surveyed by the other authors of this memoir in 1906.

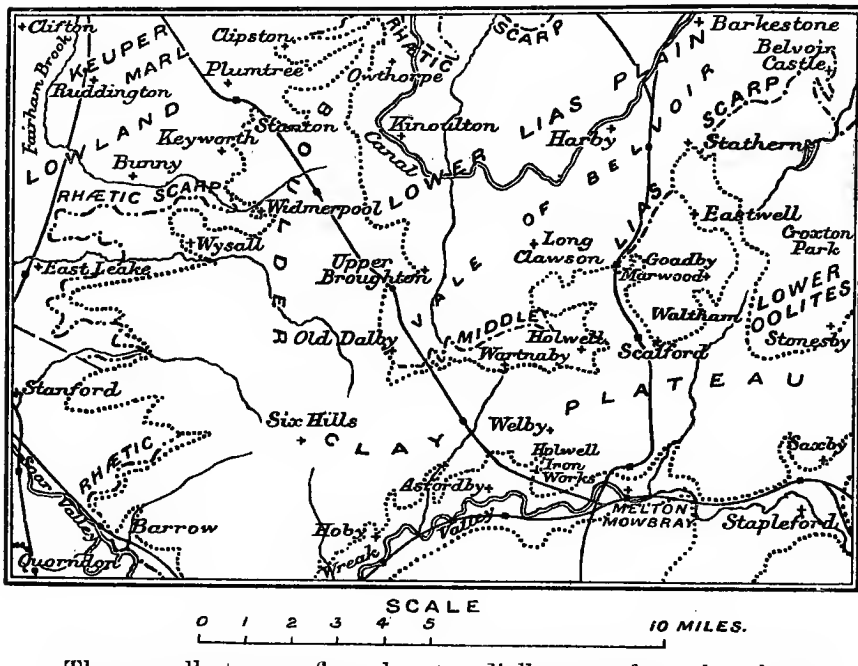
Physical Features and Geological Structure.

The whole area of the map lies within the drainage basin of the Trent. This river just touches the extreme north-western corner of the tract, at Clifton; and its important tributary, the Soar, crosses the south-western corner between Barrow and Stanford. The Wreak, a feeder of the Soar, with its eastern prolongation, the Eye, drains most of the southern area before swinging across the

[1] By G. W. Lamplugh.

southern margin at Brooksby. The other streams are of less importance, being the minor feeders of the Wreak and Soar in the south and south-west; Fairham Brook in the north-west; and the upper waters of the Smite and Devon in the north and north-east.

Fig. 1.—*Area of Sheet* 142 (*Melton Mowbray*).



These small streams flow almost radially away from the plateau of boulder-clay in the south-western part of the map; and from the prominent escarpment of Middle Lias Marlstone against which the drift is banked, in the eastern part. The relation of these streams to the drifts indicates that the subsidiary drainage system has been developed since the glaciation of the district.

In aspect, the whole area is an undulating country of low relief, ranging from about 100 ft. above sea-level in the lowest valleys to over 500 ft. on the uplands; the highest points being on the Middle Lias escarpment north of Ab Kettleby (560 ft. above O.D.), and on the Inferior Oolite at Waltham-on-the-Wolds (573 ft.). The dominant physical features are dependent upon the characters of the underlying rocks. It is the purpose of the following introductory notice of the strata, in upward succession, to bring out this relationship.

The general dip of the rocks is very gently toward the south-east or ESE., so that the oldest strata crop out in the western part of the sheet and newer beds set in successively as we go eastward.

Keuper Marl.—The red and greenish-grey marls of the Upper Keuper, which occupy the north-western corner of the area and extend all along its western margin, are the oldest strata

exposed at the surface. They form undulating low ground, bounded on the east by the steep escarpment of the Rhætic and Lias ; and they also run for some distance up the deeper valleys by which this escarpment is notched. Only the upper part of the formation is represented in this map, the outcrop revealing not more than about 300 ft. of strata, while the full thickness as determined by borings (*see* p. 12) is at least 630 ft. The predominant deep red colour of the marls disappears near the top of the formation, the uppermost 20 ft. or so being of a pale greenish tint and of distinctive aspect, whence this portion of the series is known as the 'tea-green marl.' At a few feet below the base of the tea-green marl irregular deposits of gypsum frequently occur among the marls, though not so abundantly in this area as in the country immediately to the north and west, in Sheets 126 and 141.

The Keuper Marl appears to have been deposited in an inland sea or salt lake, and there is evidence that arid desert conditions prevailed during the period on the surrounding lands. In this district, so far as is known, it is entirely unfossiliferous.

Rhætic Beds.—These beds were formerly included with the overlying Lias, but they are now regarded as the uppermost subdivision of the Trias, and are separately indicated on the map. They consist of black and grey shales with thin lenticular bands of limestone in the upper part, the whole series being about 30 ft. thick. Their outcrop forms a narrow belt along the upper slopes and crest of the low escarpment overlooking the Keuper flat. Where not obscured by glacial drift, this escarpment may be traced continuously from the eastern side of the Soar valley in the SW. corner of the map to the northern margin beyond Owthorpe, and the outcrop also loops back into the map in two valleys farther eastward, at Colston Basset and at Langar.

The Rhætic contains a limited set of fossils belonging to marine types, but apparently developed under peculiar and somewhat unfavourable conditions. It represents the transition from the inland sea of the Keuper to the open sea of the Lias.

Lower Lias.—In superficial extent, the Lower Lias is the most important formation of the map, its outcrop occupying two-thirds of the total area, if we include the tracts in which it is covered by the glacial deposits. It consists principally of dark blue shales, weathering at the surface to stiff brown or grey clay, with which are intercalated occasional thin bands of hard limestone. These flaggy limestone-bands are most abundant at the base of the series, where they are extensively dug for making hydraulic cement. They also occur at more widely-spaced intervals through the greater part of the sequence, becoming, however, quite rare and inconspicuous in the uppermost portion. They usually form slight ridges or 'features' along their outcrop, by which their course may be traced ; and it is to their presence that the above-mentioned sharp escarpment at the base of the formation is mainly due.

As a whole, the Lower Lias, where not covered with Boulder Clay, has been denuded to a broad longitudinal valley, bordered on the one side by the dip-slope of the basal limestones, and on the other side by the steep edge of the Middle Lias Marlstone. An

ill-defined portion of this depression in the north-eastern part of the map is commonly known as the Vale of Belvoir, and as the application of the term appears to be vague, it may be conveniently used to cover the well-marked lowland of Lower Lias which extends south-westward until abruptly terminated by the plateau of Boulder Clay stretching from Owthorpe to Old Dalby. This plateau-drift covers nearly all the western and southern portions of the Lower Lias outcrop in the map, so that in these parts it is only in the deeper valleys that the formation is actually exposed at the surface, or is directly responsible for the shape of the ground. The total thickness of the Lower Lias is about 650 feet.

Middle Lias.—The lower part of the Middle Lias consists of bluish clay or shale, somewhat sandy in places, but not differing much in composition from the Lower Lias, and practically indistinguishable from it except by means of its special fossils. Therefore this portion, which is estimated to be about 100 ft. in thickness, presents no individuality in the shaping of the ground, but simply forms a prolongation of the Lower Lias clayey country.

It is otherwise with the upper part of the Middle Lias, known as the Marlstone, which is very distinct in its lithological characters, being a relatively hard calcareous sandstone overlain by or passing up into a highly ferruginous rock which makes a valuable iron-ore. This indurated Marlstone has given rise to a bold escarpment—the most sharply defined feature within the map—rising abruptly for 200 to 300 ft. above the Vale of Belvoir and stretching unbrokenly for 12 miles, from Belvoir Castle to the neighbourhood of Old Dalby. In this escarpment the Marlstone division, which does not exceed 40 ft. in thickness, forms a protective capping to the underlying clays that build up the greater part of the slope. For the most part, the ground rises well above the 500 ft. contour along the crest, attaining its maximum elevation of 560 ft. above O.D. at Broughton Hill near Ab Kettleby. The escarpment between Stathern and Belvoir Castle being well-timbered and charmingly picturesque is one of the celebrated view-points of the Midlands.

The dip-slope of the Marlstone, where not obscured by drift, forms a plateau inclining gently south-eastward. The ironstone is exposed at the surface on this plateau and has already been removed by shallow workings over a considerable portion of the outcrop. In its northern part, between Belvoir and Eastwell, the plateau has been deeply dissected by the ramifying valleys at the head of the River Devon, which are cut down into the underlying clays; and similar conditions recur farther southward, around Scalford and around Holwell, at the heads of small streams tributary to the River Wreak. Being a permeable rock, the Marlstone throws out numerous springs at its base, from which these streams are principally fed.

West of Scalford, the Marlstone runs in a long tapering spur to Old Dalby, having the underlying clays to the south as well as to the north of it. This spur denotes a slight change in the direction of the dip, or possibly a very shallow synclinal structure. The termination of the spur and its southern edge are overlapped and obscured by the great sheet of Boulder Clay which covers the rest of the country in this direction. Considering the wide

extension of the Boulder Clay to the westward as well as to the southward, it is remarkable that such a large proportion of the Marlstone outcrop should be free from this covering.

Upper Lias.—The dark clays of the Upper Lias, overlying the Marlstone, occupy a narrow belt which swings into the eastern part of our district in a short loop, entering on the north near Croxton Park, running thence to Scalford and back to the eastern margin south of Stonesby. The greater part of the outcrop is, however, hidden under Boulder Clay so that the actual boundaries are often uncertain. Where not thus hidden, as between Branston and Croxton Park, it forms a sloping tract of stiff clay-land, rising sharply to the escarpment of the Lower Oolites. The thickness of the Upper Lias is about 120 ft. Like the rest of the Lias in this district it is a purely marine deposit, though its lowest beds indicate shallow water.

Lower Oolites: Northampton Beds.—The tract lying within the above-described loop of Upper Lias in the eastern part of the map is occupied by the two local subdivisions of the Lower or Inferior Oolite known respectively as the Northampton Beds and the Lincolnshire Limestone.

The lower portion of the Northampton Beds (the "Northampton Sand") consists of ferruginous sand-rock, passing in places into an ironstone which was formerly mined near Waltham. The thickness of the sand-rock is usually about 24 ft. Where not obscured by drift, as in the neighbourhood of Croxton Park, its outcrop is marked by a well-defined bank capping the slopes of Upper Lias clay, but the overlapping of the Boulder Clay and the faulting near Waltham destroy the continuity of this feature and cause difficulty in tracing the division in some places. Its fossils prove that the sand is of marine origin.

The upper part of the Northampton Beds (the "Lower Estuarine Series") consists of a variable group of grey and blue laminated clays and soft yellow sand, 15 to 20 ft. in thickness, which appears to be of estuarine origin. It is at present very sparingly exposed in the district and occupies a strip of featureless flat ground.

Lincolnshire Limestone.—The uppermost of the 'solid' formations shown on the map is the Lincolnshire Limestone which covers a tract of about 2 sq. miles between Waltham and Croxton, and is faulted in again a little farther westward as a long narrow outlier running north from Waltham. In composition it is a tolerably well-bedded cream-coloured limestone, more or less oolitic, containing many marine fossils. Only the lower part of the limestone, to a thickness not proved to exceed 26 ft., enters the map; and instead of presenting the remarkably bold feature by which it is generally characterized in Lincolnshire, the edge of its outcrop has for the most part hardly any effect upon the surface-relief. Nevertheless, the plateau wherein it is developed contains the highest ground within the map, reaching 573 ft. at Waltham and 571 ft. on the road NW. of Croxton Park.

From the Keuper Marl up to the Lincolnshire Limestone, the formations represent a practically unbroken sequence of sediments,

lying evenly one above another, without conspicuous unconformity, and all affected equally by the very gentle tilting which has produced the prevalent south-easterly dip of the strata. The remainder of the Mesozoic formations and the entire Tertiaries are unrepresented in the district, pre-glacial denudation having swept away such later deposits as may once have existed. It was not until the Pleistocene glaciation of the country that any permanent addition was made to the stratigraphical sequence as we now find it.

Glacial Deposits.—In the southern part of the map, the whole country up to the margin of the Soar valley is covered by a great sheet of Boulder Clay, so that, as already mentioned, it is only in the bottoms of the deeper valleys in this tract that the 'solid' formations reach the surface. The matrix of this Boulder Clay has been derived principally from the Liassic and other argillaceous Mesozoic deposits, while the stones and boulders which are embedded in this matrix include abundant fragments of Chalk, Chalk-flints, Lincolnshire Limestone, Middle Lias Marlstone, Lower Lias limestones and many quartzite pebbles from the Bunter, together with less abundant blocks of sandstone and limestone from the Carboniferous formation and a few igneous rocks of still more distant origin. Many of the boulders are characteristically striated; and the whole evidence warrants the deduction that the Boulder Clay is the product of an ice-sheet which swept over the district.

The Boulder Clay has levelled up all the minor inequalities of the pre-glacial surface, and its thickness is therefore very irregular, ranging up to at least 150 ft. in the old hollows. It appears originally to have formed a gently undulating plateau, rising to nearly 500 ft. above sea level between the valley of the Wreak and the Vale of Belvoir, but declining gradually northward. This plateau is, however, now much dissected by the steep little valleys that carry away its drainage on all sides, so that the boulder-clay country is for the most part sharply and irregularly undulating.

The main plateau of Boulder Clay has a tapering prolongation northward which reaches just beyond the northern edge of the map. Upon the eastern side of this lobe there is usually a sudden fall of the ground for at least 100 ft., the slope consisting of Lower Lias capped by Boulder Clay. The driftless plain of the Vale of Belvoir extends up to the foot of this feature which appears to owe its origin to the Boulder Clay and to be, in fact, a boulder-clay escarpment.

Along the western margin of the drift plateau the glacial deposits include numerous masses of stratified sand and gravel; and similar masses occur also along the Wreak valley and in a few other places. They appear to be mostly the product of waters draining the edge of the ice-sheet at various stages of its advance and retreat. They are too limited in extent to have much influence upon the topography, though occasionally in the Keuper area of the north-western part of the map they cap small isolated hills, perhaps due to their protection; and in a few other places, particularly at the head of the Devon south of Belvoir, they form narrow high-lying terraces within the valleys.

POST-GLACIAL DEPOSITS. — Since the deposition of the Boulder Clay the erosion of the district has been very considerable, so that there are wide-spread river deposits in the larger valleys. Thus, the valleys of the Soar and Wreak are flanked by broad terraces of flood-gravel lying 20 to 30 ft. above the present alluvial flat. The older of these terraces probably date back to the close of the Glacial period, as the remains of extinct mammalia, including the mammoth, have been found in them. Since that time the streams have diminished greatly in volume and have formed their lower flats of silt and loam. On the soft clays of the Lias even these lower alluvial flats are disproportionately wide in relation to the meagre streams with which they are associated. The flat ground likewise frequently extends on both sides beyond the actual limits of the stream-deposits, probably owing to the rapid weathering down of the perishable strata (p. 88). But where the streams cross the outcrop of harder beds, as, for example, the Hydraulic Limestones of the Lower Lias, their flats become narrow and sharply defined (p. 26).

Besides the alluvium of the streams, there is a wide flat of about 3 square miles in the Keuper country west of Bunny, including Gotham Moor, Ruddington Moor and Bunny Moor, which appears to have formed the site of a shallow lake, and probably persisted as an occasionally flooded bogland until artificially drained. This tract is the largest patch of alluvium in the map.

PREVIOUS LITERATURE.

As the area possesses no formations that are peculiar to it, and as its strata are very sparingly exposed save in the workings of gypsum in the Keuper, of the hydraulic limestones in the Lower Lias and of the ironstones in the Middle Lias, its geology has not attracted much attention, and the literature is therefore somewhat scanty.

So much of the eastern portion as fell within Sheets 64 and 70 of the Old Series Map was described in detail in previous memoirs of the Survey accompanying these sheets, and an account of some of the ground in the southern part of the map (partly reproduced in the present work) was incorporated by Mr. C. Fox-Strangways in his Survey memoir on the adjacent New Series sheet published in 1903; ("Leicester," Sheet 156). A short account of the Jurassic rocks of the district is contained in the general memoir on the Jurassic Rocks of Britain, vols. iii and iv, by Mr. H. B. Woodward.

By independent observers there have been special descriptions of the more interesting local developments of particular formations within the district; among these may be mentioned important papers on the Rhætics, by E. Wilson and H. E. Quilter; on the Lower Lias and its fossils, by H. E. Quilter; on the Middle Lias Marlstone, by E. Wilson; and on the Glacial deposits, by R. M. Deeley. To these papers full references are given in subsequent pages and in the Bibliographical Appendix (pp. 108–9). The interesting series of fish, reptile and insect remains obtained from

the cementstone quarries at Barrow-upon-Soar have furnished the subject-matter for several papers of descriptive palæontology, to which, again, references are given in the Appendix.

Besides these specialized works, the main outlines of the geological features of the district have been described incidentally in the more generalized articles on the geology of Nottinghamshire and Leicestershire referred to in the Appendix to this memoir.

TABLE OF FORMATIONS.

The following formations, briefly described in the foregoing pages, are represented on the map :—

Superficial Formations.

		Recent	Alluvium.
Pleistocene	Post-glacial		River-gravels, loam, etc.
	Late-glacial		Older river-gravels, loam, etc.
	Glacial	Sand and gravel.	
		Boulder Clay, with brickearth or loam.	

Solid Formations.

Jurassic	Inferior Oolite.	Lincolnshire Limestone		Pale limestone.
		Northampton Beds.	Lower Estuarine Series.	Pale laminated clay and sand.
			Northampton Sand.	Ferruginous sandrock.
	Lias	Upper Lias		Dark shaly clays.
		Middle Lias	Ferruginous limestone, ironstone and calcareous sandstone (Marlstone).	
			Sandy shales and clays.	
		Lower Lias		Shaly clays with thin limestones.
Triassic		Rhætic	Black and grey shales with thin lenticular limestone in upper part.	
		Keuper Marl	Red, green, and mottled marls with thin sandstones and gypsum.	

CHAPTER II.

CONCEALED CARBONIFEROUS AND OLDER ROCKS.[1]

While the Keuper Marl is the oldest formation to reach the surface and therefore to be shown on the map, some evidence is forthcoming from deep borings in the NW. part of the sheet respecting the buried floor of older rocks beneath the Trias.

In the Soar valley, south of Quorndon and only just across the southern margin of the map, the Pre-Cambrian granitic rocks of Mount Sorrel come to the surface from beneath a mantle of Keuper Marl. In the same valley near Hathern, 3 miles SW. of East Leake, two borings[2] passed from Trias into the Pre-Cambrian "Charnwood Forest Rocks"; but in borings at Ruddington, Owthorpe and Edwalton, to the east of the Soar valley, the Trias was found to rest on Coal Measures. These are the only places at which the Palæozoic and older rocks have as yet been proved within or in the proximity of the area included in Sheet 142.

The Ruddington boring commenced in Keuper Marl and entered the Coal Measures at a depth of 687 ft. below the surface. The character of the measures above and below one of the coals at 1072 ft. in depth proves this seam to be the Alton; and its identification is corroborated by the nature of the shale roof, in which Mr. R. D. Vernon has recently found the marine fossils characteristic of this horizon throughout the Derbyshire Coalfield.[3] At 1131 ft. the boring entered the First Grit of the Millstone Grit Series and was continued to a total depth of 1870 ft. 4 in., the last 109 ft. being bored in the Kinderscout Grit of the same series.[4] Here again, as in the case of the measures above and below the Alton Coal, the sequence closely resembles that recognized in the Derbyshire Coalfield. There can indeed be no doubt that the boring enters the Derbyshire Carboniferous sequence below the horizon of the Kilburn Coal (550 ft. above the Alton), and that it was suspended before reaching the Limestone Shales. The Coal Measures represented therefore lie many feet below the Middle Coal Measures of Derbyshire where over 1000 ft. of strata separate the Alton Coal from the Black Shale or Silkstone Coal which is there taken as the base of the Middle Coal Measures.[5]

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[1] By W. Gibson.

[2] "The Geology of the Leicestershire and South Derbyshire Coalfield." *Mem. Geol. Surv.*, 1907, pp 358–359.

[3] "Geology of South part of the Derbyshire and Nottinghamshire Coalfield." *Mem. Geol. Surv.*, 1908, p. 100.

[4] For further details see the abridged record of the boring in Appendix I, p. 105, of this memoir, or the fuller section given in "The Geology of the Country between Newark and Nottingham." *Mem. Geol. Surv.*, 1908, Appendix I. pp. 112–113.

[5] "Geology of South part of Derbyshire, etc., Coalfield," p. 60.

At Owthorpe, 6 miles east of Ruddington, the Coal Measures were entered at a depth of 1069 ft.; and after passing through several seams of coal the boring was discontinued at a depth of 2032 ft.[1] In this sequence the fossil-evidence and character of the strata prove them to belong to the measures above the Black Shale Coal of Derbyshire. Unfortunately the identification of the seams of coal passed through is not fully established, though there are reasons for taking the coal (4 ft. 8 in. thick) at 2012 ft. in depth to be equivalent to the Top Hard Coal of the Nottinghamshire Coalfield.[2] If this determination be correct, the position of the Alton Coal at Owthorpe should be about 3400 ft. below O.D. as compared with 972 ft. at Ruddington. Supposing there is no faulting, the dip between the two localities amounts to over 1 in 15, or a little under 4 degrees. Owthorpe, however, is not situated in the direction of full dip with respect to Ruddington, for in a boring ¾ mile NE. of Edwalton Church and 3 miles NE. of Ruddington, the Alton Coal lies approximately 2200 ft. below O.D. The inclination between Ruddington and Edwalton is therefore about 1 in 13 or a little over 4 degrees. From the estimated depth to the Alton Coal at these three points we may deduce that the strike of the Carboniferous rocks is roughly N30W. If this direction is maintained to the SE., the Coal Measures should be present beneath the Secondary rocks over the whole area east of a line joining Ruddington and Melton Mowbray, but the depth to the productive seams would be great within the outcrop of the Middle Lias and Oolites.

It must be acknowledged, however, that the determination of the strike of the Carboniferous rocks between Ruddington and Owthorpe is based on somewhat slender evidence. If reliable, it would lend support to the conclusions reached by Prof. P. F. Kendall as to the southerly extension of the Nottinghamshire Coalfield beneath the Secondary formations of Leicestershire and Rutlandshire.[3]

In his report to the recent Commission on Coal Supplies, Prof. Kendall postulates an extension of the Coal Measures up to the margin of the Fen country and therefore far beyond the south-eastern limits of the present map. This extension is based on the connexion existing between the distribution of the Carboniferous rocks and the Charnian ridge, of which the strike agrees with that of the Coal Measures as deduced from the Ruddington and Owthorpe borings. In calculating the future coal supply, however, the Commissioners limit the probable extension of the concealed coalfield to about the latitude of Melton Mowbray, though they recognise that the arguments advanced by Prof. Kendall are based on the only data at present available.

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[1] *See* Appendix I., p. 104, and "Geology of the Country between Newark & Nottingham." pp. 106–8.

[2] "Geology of the Country between Newark and Nottingham." *Mem. Geol. Surv.*, 1908. p. 18, 19.

[3] "Final Report of the Royal Commission on Coal Supplies." Part IX, 1905, p. 19, and pp. 24–28.

While the evidence as to the composition of the pre-Triassic platform is very scanty, the shape of the buried surface is still more problematical. Between Ruddington and Owthorpe, and again between Ruddington and Edwalton, its slope appears to be gentle; the general direction of fall being eastward. Analogy with the proved pre-Triassic surface in the concealed coalfield between Nottingham and Doncaster favours the idea that north-east of a line joining Ruddington and Melton Mowbray the concealed Palæozoic surface has similarly a slope to the east at a gentle angle and does not present those irregularities met with around the Leicestershire Coalfield.

CHAPTER III.

TRIAS.[1]

Keuper.

GENERAL ACCOUNT.

This division of the Trias is represented on the present map by the upper part of the Keuper Marl only, the lower part of the Marl and the Waterstones outcropping in the area to the north (Sheet 126). It occupies the north-western part of the present sheet, with an interrupted extension along the northern margin of the map as far eastward as Langar; together with a tract in the southwest, in the valleys of the Soar and Wreak, where however it is greatly obscured by drift and alluvial deposits.

The Keuper is known from the first Owthorpe[2] boring, which penetrated the whole of the formation, to be 748 ft. thick at that place, of which 121 ft. is referred to the Waterstones and 627 ft. to the Keuper Marl. The Ruddington[3] boring commenced below the top of the Keuper Marl and passed through 386 ft. of Marl and 73 feet of Waterstones.

The thickness of the Keuper Marl which actually outcrops in the district we are describing, is probably between 300 and 350 ft. The dip of the beds can rarely be ascertained by direct observation, but, estimating from the known thickness, the width of the outcrop, and the inclination of the overlying rocks, it appears to average about 1° to the SE., though it is doubtless affected locally by the small undulations recognizable in the Lias.

No fossils are known from the Keuper of our present district although a few have been recorded from near Leicester,[4] where they were chiefly found in a local development of the 'Upper Keuper Sandstone,' and include the relics of reptiles, fish and plants.

The physical aspect of the country is somewhat different from that of the Keuper area north of the Trent, owing to the comparative rarity of the sandy rock-bands or 'skerries' so prevalent in the lower part of the Marl. Instead of the regular features produced by the skerries the country is irregularly undulating, with occasional conspicuous hills, usually crowned by patches of sandy drift.

The rock is, typically, of a decided red colour, and has a clayey texture though very largely composed of fine siliceous silt with an admixture of calcareous and clayey matter. Usually it breaks up into angular pieces with the characteristic 'marly' fracture, and in dry weather is reduced readily by agricultural operations to a loamy soil. Where well exposed, its bedding is usually distinct and is accentuated by the presence of green streaks and bands. The

[1] By R. L. Sherlock and B. Smith.

[2] "Geology of the Country between Newark and Nottingham." *Mem. Geol. Surv.*, 1908, pp. 24 and 106. *See also* Appendix I. of present memoir, p. 104.

[3] *Ibid.*, pp. 24 and 112. *See also* p. 105 of present memoir.

[4] C. Fox-Strangways, "Geology of the Country near Leicester." *Mem. Geol. Surv.*, 1903, p. 96. A. R. Horwood, "Notes on the Palæontology of Leicestershire." *Brit. Assoc. Handbook*, 1907, p. 312.

green bands are sometimes marly, but more generally are composed of fine loamy sand or silt. The skerry-sandstones, as already mentioned, are relatively scarce in this part of the marl, and the only example which could be traced out on the map occurs near Glapton.

Gypsum beds of economic importance occur at two horizons. The higher, which is mined and quarried 1 mile NE. of Owthorpe, is on the horizon of the Newark deposits, *i.e.*, near the top of the red marls; the lower, mined at Sharpley Hill, East Leake, lies at about 180 ft. below the Rhætic.

The uppermost 15–30 ft. of the Keuper Marl throughout the area is of a pale green, or greyish, colour. This 'Tea-green Marl,' as it is called, was, at one time, classed with the overlying Rhætic, which was included with the Lias. The classification now adopted, by which it is united with the Keuper, was established, in this district, mainly by the researches of Edward Wilson[1], who confirmed the views as to its relationship arrived at in other parts of the country by Dr. T. Wright[2] and others. Except in colour the Tea-green Marl does not differ from the red marl below, and it is generally considered that the difference in colour is due to subsequent chemical change.[3] It possesses, however, a more persistently massive homogeneous structure than most parts of the red marl, and its fracture, in consequence, is usually conchoidal or spheroidal in unweathered sections.

In the present area the Tea-green Marl forms the lower part of a prominent escarpment, crowned by Rhætic and Lias, or by drift. Its thickness appears to be about 30 ft. between East Leake and Clipston, but diminishes somewhat when followed north-eastward.

Some topographical details will now be given respecting the outcrop of the red marls, which for this purpose will be divided into a north-western area and a south-western area. The Tea-green Marl will then be dealt with under a separate heading.

DETAILS.

North-western Area.—One of the best sections in the Keuper Marl of this area is exposed by the Great Central Railway, which, at the northern limit of the map, runs through a cutting about 24 ft. deep, showing the following details :—

	ft.	in.
Red marl and talus	7	0
'Skerry' sandstone	2	6
Red marl, unusually sandy	5	0
'Skerry' sandstone	0	1
Red marl, laminated	2	6
'Skerry' sandstone, grey and laminated	0	2
Talus	7	0

North of Clifton the country has a loamy pebbly soil, due to the remains of sandy drift, and also partly to the outcrop of small skerry bands. At the sharp

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[1] "The Rhætics of Nottinghamshire." *Quart. Journ. Geol. Soc.*, vol. xxxviii. 1882, p. 451.

[2] "On the Zone of Avicula contorta and the Lower Lias of the South of England." *Quart. Journ. Geol. Soc.*, vol. xvi., 1860, p. 374.

[3] Recently, however, Dr. Moody has upheld the view that it is the green colour which is original, and that the redness of the underlying beds is due to secondary change. ("The Causes of Variation in Keuper Marls and in other Calcareous Rocks," *Quart. Journ. Geol. Soc.*, vol. lxi., 1905, p. 431.)

bend in the road to Ruddington, south of Glapton, there is a gully, about 12 ft. deep, in red marl with a 4 in. skerry and some green marly bands. The skerry, indicated on the map, may be traced by its surface-feature and its debris in the ploughed land, into Clifton Pasture, where it is masked by drift. The sharp rise at Glapton Wood appears to be composed of red marl to the summit, and there is no indication that the prominence is due to the presence of a skerry.

In the much-obscured railway cutting at Edwalton, a band of white sandrock, about 18 in. thick, dipping gently to NW., was noticed near the Nottingham road, and other traces of the same rock were seen in the vicinity.

From Ruddington and Bunny to Plumtree and Normanton there are no sections deeper than a few feet. Much of the country has a loamy soil, especially along a belt between Ruddington and Flawforth House, which may be due to the outcrop of a skerry, while other parts are modified by the weathering of patches of sandy drift. From Tollerton and Clipston to Plumtree the soil is red clay, and numerous small sections of red marl may be seen in the banks of the brook flowing through Tollerton.

The highest beds of the red marls crop out in the lower slopes of Hoe Hill, where they plough up as stiff clays. On the NW. side of the hill some fragments of hard skerry and lumps of gypsum were thrown out from the bottom of a well sunk at the junction of the green and red marls to a depth of about 35 ft. The gypsum here corresponds to the position of the Newark deposits.

The broad tract of alluvium extending from Bunny to Gotham rests on Keuper Marl with some sandy drift intervening, and there are indications that the belt of gypsiferous strata worked at Gotham and East Leake outcrops beneath this alluvium.

Between Bunny and Costock, at the 8th milestone from Nottingham, a brickyard in the upper part of the marls shows 2 ft. of red clay resting on a lenticle of green sandy marl having a maximum thickness of 1½ ft., and this lies on red marl exceeding 25 ft. in thickness without any admixture of skerry. The brickyard is cut into a terrace-like feature which is often visible at the foot of the Rhætic escarpment, but which comes in and dies out again rather suddenly and is not strictly parallel to the escarpment behind it. The only evidence as to the origin of the feature is afforded by the above-mentioned section, where the sandy band may represent the horizon of a sandstone which occasionally becomes capable of forming a terrace.

The wood NE. of Stanford Hills Farm is known as Brickyard Spinney, and small excavations in it indicate that clay for bricks has formerly been dug here.

R. L. S.

Near the northern margin of the map the highest part of the red marls is well exposed at the Cotgrave Brickyard, 450 yds. SSW. of The Gripps, where the excavation into the hillside has reached back almost to the base of the Rhætic which here forms the top of the escarpment.

The section exposed in 1906 was as follows :—

	ft.
Tea-green marl ... ... seen to	16
Red marl	9
Thin green band with skerry	
Red marl	6
Thin green band with skerry forming the main floor of quarry	
Red marl with 'balls' of gypsum	12
	43

The 'balls' of gypsum occur at some 24 ft. below the Tea-green Marl, being approximately at the horizon of the gypsiferous beds at Newark. The bands of skerry seen in the section do not cause any surface features.

The largest exposure of the Keuper Marl in this part of the map is that revealed in the workings of the Snaith Plaster and Cement Co., S. of Cropwell Bishop (Sheet 126), on the E. bank of the Grantham Canal 600 yds. N. of the bridge at Blue Hill. Gypsum was first raised here by quarrying, but it is now[1] chiefly extracted by horizontal galleries driven along the more promising beds.

[1] We understand that the deeper workings were undertaken at the suggestion of the late R. Etheridge, F.R.S.

The open pit shows the following section :—

	ft.	in.
Red marl } with balls of gypsum	1	4
Green marl }	3	6
Red marl occasionally mottled green, with 5 or 6 beds of gypsum	30	6
White gypsum roof, stained blue-green ...	0 to 1	3
Red marl	4	0
White gypsum floor, often stained blue-green ...	0 to 1	3
	about 42	

Gypsum over 1 ft. thick occurs below the floor of the pit.

The lower part of the section is practically identical with that of the Gotham Plaster Company's working just N. of the limits of the present map, described in a previous memoir.[1]

The white gypsum floor is reputed to be the equivalent of the deposit which gives the most profitable yield at Newark. The balls of gypsum, occurring in the upper few feet of the section, that is, about 20 ft. below the base of the Tea-green Marl, vary in size from an average of 6 to 10 ft. in horizontal diameter, to a maximum of 14 ft., and their occurrence is quite sporadic. They are much valued because of the high quality of the gypsum in their interior. They are located by the workmen by means of boring or probing, and are then reached and extracted by sinking circular pits. The balls usually have somewhat the outlines of a plano-convex lens, resting upon its flat base. The clean crystalline gypsum of the interior of the ball passes outward into a mixture of marl and gypsum, which changes laterally into the ordinary marl. The marl occurring on the horizon of the balls is said to abut against their convex surfaces, and not to be moulded upon or arched up by them, but no opportunity was found of confirming this observation.

The two beds forming the roof and floor of the tunnels are generally of massive gypsum, often stained pink and bluish-green by incorporated marl, but they occasionally become fibrous and platy, forming what is known to the workmen as 'mother,' and occasionally they tail off in thin vein-like strings.

The higher and thinner bands show similar variations in a more pronounced degree. In the fibrous 'mother' the fibres are always vertical, whatever may be the inclination of the plate or vein itself.

B. S.

The South-western Area.—A disused brickyard at the foot of Sutcliffe Hill, Rempstone, shows 8 feet of red marl. Small pockets of sandy gravel and green clay are let down into it near the top and indicate the origin of the loamy pebbly soil which so frequently caps the Keuper Marl.

Between the Normanton Hills fault[2] and Stanford upon Soar the soil is a red clay modified by sandy downwash from the drift which caps the Hoton Hills. About 7 ft. of red marl may be seen in the roadside 200 yds. N. of Underhill Farm, and on the rising ground south of the King's Brook there are some large disused marl-pits without sections.

The little valley between Hoton Hills and Hoton has been excavated through the drift-plateau into the Keuper; and at the intersection of roads N. of the village, a small pit shows 18 ins. of red clay soil overlying 18 ins. of greenish-grey skerry, which rests on red marl.

It will be seen from the map that southward from Cotes the Keuper Marl is only exposed in a narrow belt on the slopes of the valleys, between the plateau-drift and the alluvial terraces of the rivers. Even this limited outcrop is generally masked by hillwash, so that it is only in an occasional brickyard or marl-pit that the marl is actually seen.

The best exposure in this tract occurs at the small brickyard situated at the end of a low spur 300 yds. NE. of Walton Grange, which reveals about 20 ft. of red marl with an irregular capping of drift gravel up to 4 ft. in thickness. A lumpy band of gypsum is visible at the bottom of the pit and its outcrop can be

[1] "Geology of, etc., Newark and Nottingham." *Mem. Geol. Surv.*, 1908, p. 52.

[2] *See* "Geology of the Country between Derby . . . and Loughborough." (Sh. 141.) *Mem. Geol. Surv.*, 1905, p. 48; also present memoir, p. 17.

followed for about ½ mile in either direction by the traces of old excavations from which the mineral has been dug. It is probable that the gypsum is on the horizon of the bands worked near East Leake and Gotham, and that it is below the horizon of the Newark deposits.

In the Wreak valley the Keuper Marl is brought in on the south, between Cossington Gorse and Rotherby, by the Barrow and Sileby[1] fault. The fault is readily distinguished where it crosses the Ox Brook, Thrussington, the blue Liassic clays and limestones being here thrown against red and grey Keuper marl in the stream section. Except at this place and in the bottom of the little valley 500 yds. SE. of Cossington Gorse, the outcrop of the Keuper is obscured by drift or by the valley deposits.

R. L. S.

Tea-green Marl.—In the north-easterly portion of its outcrop in the map, between Langar and Blue Hill, NW. of Colston Basset, the Tea-green Marl is poorly exposed, but its limits are readily traceable by the physical feature; by the colour and character of the soil; and by the occurrence of small springs which issue from the base of the Rhætic beds. These springs have been frequently utilized as the sites for wells and ponds, which partly conceal their points of issue. Several occur north of the scarp at Langar and feed the Fish Ponds at Langar Hall.

In an old brickyard 200 yds. NE. of Blue Hill, at the base of the Rhætic feature, bricks were made from Tea-green Marl, which is still sparingly visible in the overgrown excavation. A good spring from which the water supply of Home Farm near Colston Basset is drawn, is thrown out by the Marl, which appears to have a maximum thickness of about 15 ft. in this part of the district. Its thickness increases westward, however, as in the section at Cotgrave brickyard, as previously described, not less than 16 ft. of the Tea-green Marl is exposed, and we must allow about 4 ft. more to reach to the base of the Rhætic shales. The outcrop SW. of this exposure is much obscured by drift, but the green beds are again clearly seen W. and S. of Blackberry Hill, and they are probably thicker here than at Cotgrave. They are visible in several places in the banks of the little stream S. of Blackberry Hill, extending up to a few yds. E. of the road-crossing, while immediately above this point fragments of black Rhætic shales were found in the banks.

In the next little valley to the south the junction between the Tea-green Marl and the Rhætic black shales is marked by a spring 200 yds. NNW. of Hill Farm. In both valleys the marl forms gently sloping ground beneath the steeper slope of the Rhætic beds, and it gives rise to the characteristic grey or yellowish-grey clay soil.

B. S.

In the Mid. Ry. cuttings SE. of Plumtree Station, the green marl is still visible under the drift, though the section is now much obscured (*see* p. 77). The road from Plumtree to Stanton also reveals the green marl in a cutting to a depth of about 15 ft. No other noteworthy section occurs until we come to the accommodation road S. of Keyworth, on the east of which the bed is sparingly exposed in some old marl-pits.

In the valley of the Fairham Brook the outcrop of the green marl is much obscured by drift. West of the brook it resumes its normal aspect, forming the lower and steeper part of the combined Rhætic-Lias escarpment. For over 3 miles, however, the escarpment is covered by thick plantations, and the only evidence lies in the character of the soil and in an occasional ditch section. The valley between Crow Wood and Sharpley Hill, through which the Great Central Railway runs, cuts almost, but not quite, through the green marl, which can be seen in the railway-cutting and in pits by the roadside. On the S. side of East Leake Hills the prominent feature persists for some distance, until, east of Taft Leys, the outcrop rapidly expands and swings in a broad belt across the valley, rising again into an escarpment on the southern slope. Here, however, it soon becomes overlain by drift and does not reappear at the surface until we reach Rempstone, where it is exposed in a pit near the crossroads and in the bed of King's Brook. In this quarter the outcrop is shifted westward by the more northerly of the pair of faults shown on the map, and the green marl is next seen in the brook, alongside the artificial lake in Stanford Park. We were informed that the lake is 17 ft. deep and has a floor of green clay. As red marl

[1] C. Fox-Strangways, 'Geology of the Country near Leicester.' *Mem. Geol. Surv.*, 1903, p. 58.

is exposed in the bank on the N. side of the lake, we must assume that the Keuper possesses a somewhat high dip in this locality, which may be accounted for by the proximity of the fault. An unfinished well beside the high road opposite the lodge at the NE. corner of Stanford Park had, in 1906, been sunk to a depth of 42 ft. in red marl, and proved the absence of the Tea-green Marl there.

The more southerly or Normanton Hills fault cuts off the outcrop of the green beds, along with that of the Rhætic, and carries it south-eastward into an area thickly covered by drift. Where the base of the Rhætic again emerges, in the valleys between Burton-on-the-Wolds and Barrow-upon-Soar, the ground is much obscured by downwash, but the green marl is visible in the bed of Walton Brook, NE. of Walton; in a few places on the slopes of Barrow Hill; and in the Mid. Ry. cutting 600 yds. NW. of Barrow Station. On the N. side of the Wreak valley the Tea-green Marl is cut out by the Sileby Fault.

R. L. S.

RHÆTIC.

GENERAL ACCOUNT.

The Rhætics are divided by their lithological characters into the 'White Lias' above and the *Avicula contorta* Shales below, but these subdivisions are too thin to be shown separately on the map.

The lower beds of the Rhætic consist of black paper-shales with thin sandy bands. Locally they are very fossiliferous and often include a bone-bed containing fish and reptilian remains. The junction of the Rhætic with the Tea-green Marl, though rarely exposed, is always sharply marked. There may indeed be a slight unconformity at this horizon, as it has been observed that in some cases there is evidence of the green marls having been eroded before the overlying beds were deposited.[1]

The White Lias[2] consists of thick-bedded light-coloured marls with which are interbedded a few thin bands of compact argillaceous limestone, usually more or less nodular and disconnected. One of these limestones—a very fine-grained hard splintery rock—forms the top of the division. This band was formerly used for road-metal, and the traces of the old shallow pits from which it was obtained are of much aid in tracing its outcrop. The nodular limestones are blue-hearted, but often stained purple on the outside to a depth of an inch or two. They fall to pieces so readily when tapped with the hammer as to suggest that they are in a state of internal strain. Microscopically, they are found to be composed of highly calcareous mud, containing a small quantity of pyrites, a few clastic grains of quartz and some flakes of mica. When treated with acid they leave a considerable amount of insoluble residue, which is probably, in part, colloidal silica.

The thickness of the formation is variable but always small. At Barnstone (Sheet 126) the black shales are 14 or 15 ft. thick, and the White Lias is about 18 ft.; at East Leake the railway-cutting through the Normanton Hills, just over the western boundary of the map, showed about 20 ft. of the dark shales, overlain by grey shale with thin limestone, of which 12 feet was assigned to the

[1] "The Rhætics of Nottinghamshire." *Quart. Journ. Geol. Soc.*, vol. xxxviii., 1882, p. 455.

[2] Since the above was typed, Mr. L. Richardson has thrown doubt on the equivalence of these Midland beds with the 'White Lias' of Somerset, and classes them simply as "Upper Rhætics." ("The Rhætic Section at Wigston, Leicestershire," *Geol. Mag.*, dec. v., vol. vi., 1909, pp. 366–70.)

Rhætic, but which passed up into the Lower Lias with no good line of separation between them.[1]

The beds are always, as in the last-mentioned section, conformable to the Lias above, and have a slight general dip of 1 or 2 degrees towards the SE., but with gentle undulations which alter the direction locally.

The outcrop is marked by a prominent escarpment which becomes bolder as it is traced south-westward, owing to the increasing participation of the Keuper Marl in the feature. But between Clipston and Widmerpool the escarpment is often obscured by drift, as also between East Leake and Rempstone, and again south of the Normanton Hills fault.

The fossils of the Rhætic, though in places individually numerous, belong to a limited range of species, chiefly bivalve shells (lamellibranchs) of small size, and fragmentary fish remains. The best collections have been obtained from localities just beyond the limits of the map, at Barnstone[2] on the north, and at Normanton Hills[3] on the west. A few species which have been recorded from the Stanton railway-cutting or collected during the course of the recent survey are mentioned in the following detailed description of the series.

R. L. S. & B. S.

DETAILS.

The Rhætic Beds are very scantily exposed along their northern outcrop west of Langar; but here and there the black shales, or the grey marls and fine-grained limestones of the White Lias, have been disclosed in wells and ditches. The best exposure is that seen in a quarry opened on the left bank of the Grantham Canal at Blue Hill, to obtain clay for puddling, where the following section was measured :—

		ft.	ins.
	Made ground	4	0
	Brown soil with stones		6
'White Lias'	Thin band of purple-blue rather crystalline limestone with *Modiola minima*...		4
	Blue-brown calcareous shales with 'race'	1	0
	Band of thin concretionary limestone...		1
	Yellowish creamy calcareous shales with 'race' ...		9
	Creamy fine-grained concretionary limestone ...		2½–5
	Calcareous shales		9
	Nodular creamy blue-hearted limestone		3–6
	Blue-yellow calcareous shales, stained red	1	0
	Fine-grained creamy and blue-hearted septarian limestone, passing laterally into shales. Pink-purple staining outside. Manganese (dendritic) markings		6
	Grey-blue clays and marls, stained brown and red ...	2	0
	Blue-grey somewhat concretionary clays and marls with manganese stains, gypsum crystals, and fossils	7	0
	Black fossiliferous shales at water level; weathered yellow on bedding planes; containing, cf. "*Pullastra*" *arenicola* Strickl. and *Schizodus concentricus?* Moore	1	0
		19	6

[1] "The Geology of Derby, etc., and Loughborough." *Mem. Geol. Surv.*, 1905, p. 35; and M. Browne, *Rep. Brit. Assoc.* for 1895, p. 689.

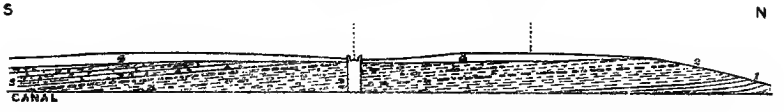
[2] *See* "The Rhætics of Nottinghamshire," by E. Wilson, *op. supra cit.*; and "The Geology of the Country between Newark and Nottingham." *Mem. Geol. Surv.*, 1908, p. 55.

[3] *See* Browne, *Rep. Brit. Assoc.* for 1895, p. 689, and "The Geology of Derby, etc. and Loughborough." *Mem. Geol. Surv.*, 1905, p. 35.

This section does not extend quite to the top of the Rhætic, which is clearly exposed, however, in a small pit at Cotgrave Gorse, presently to be described. The Canal-cutting, of which the above section forms part, has crossed all the strata from the top of the Keuper (Tea-green Marl) to the Hydraulic Limestones of the Lower Lias, but except at the quarry is now much obscured. The following generalized section has been constructed from the evidence still available.

Fig. 2.—Section through the Rhætic Escarpment at Blue Hill, Nottingham and Grantham Canal. (*B. Smith*).

Length of section, 220 *yds. Vertical scale, about* 2 × *horizontal.*



4. Made ground. 3. Lias shales and limestones. 2. Shales and marls, with concretionary limestones (White Lias). 1. Black fossiliferous Rhætic shales.

At the northern end, in the quarry, the dip is about 3° in the line of section. South of the quarry the Lias Limestones come on, well bedded and fossiliferous. North of the landing-stage they rest on a few feet of shale, below which are blue marls associated with nodular masses of compact fine-grained limestone showing a conchoidal fracture. These marls and nodular limestone represent the top part of the Rhætic, not seen in the quarry, and they add about 4 ft. to the thickness of the 'White Lias' given in the previous section, making about 17 ft. in all. The marls are often contorted and compressed laterally; they enclose small nodules of limestone and irregular hollow lumps of calcareous 'race,' and when weathered, contain numerous small crystals of gypsum.

On the NE. side of Cotgrave Gorse occurs the previously-mentioned pit showing the junction of the Lower Lias and Rhætic, the section being as follows:—

		ft.	ins.
	Soil, with irregular pockets and 'pipes' of red sand		6+
Lower Lias.	Two thin bands of pale yellowish limestone and shale: spines of echinoderms in the limestone	4	0
	Band of blue limestone with shelly layers		7
	Shale	1	3
'White Lias.'	Compact fine-grained limestone; blue hearted, with purplish exterior; splitting with conchoidal fracture	1	0
		7	4

The quarry lies a few yards to NE. of a small fault, trending through Owthorpe and Cotgrave, which brings up the Rhætic on the SW. against Lower Lias, and sets back the escarpment some 200 yds. to SE. Drains cut in the face of the hill in the Long Plantation reveal at intervals glossy black *Avicula*-shales and grey shaly marls with 'race.'

In the neighbourhood of Clipston the outcrop is obscured by drift, but at Blackberry Hill the Rhætic beds emerge again and resume their characteristic surface features. Similar features are observable in the valley N. of Stanton Tunnel, where the base of the Rhætic is marked by a copious spring as noted previously (p. 16). B. S.

Though no definite evidence was found, the position of the isolated Hoe Hill, ¾ mile SW. of Clipston, and the height of the feature above the base of the Tea-green Marl, render it likely that the hill carries a small outlier of the Rhætic shales under its thin capping of drift. This outlier probably marks the extremity of a spur-like westward projection of the Rhætic, due to a shallow east-west fold, like the similar features farther S., at Rancliffe Wood and Hotchley Hill.

The Midland Railway cutting and tunnel at Stanton-on-the-Wolds exposed a good section in the Rhætic, which, although now obscure, was carefully examined at the time by E. Wilson,[1] who recorded the following details of it :—

		ft.	in.
	"Boulder-clay with local intercalations of drift-sand ... ... 50 ft. to	60	0
Avicula-contorta shales (RHÆTIC).	Shales dark coloured, thickly laminated, with a few thin seams of sandstone and a band of nodular limestone 1 ft. 9 in. from base: *Cassianella contorta*, *Axinus elongatus*, *Protocardium Philippianum*	6	0
	Pyritic sandstone ... ... ¼ in. to	0	2½
	Shales darker and more thinly laminated than the overlying, with occasional streaks of fine white sand: *C. contorta*, *A. elongatus*, *P. Philippianum*...	3	0
	Pyritic limestone, with *A. elongatus*, *Modiola minima*, fish scales, sun-cracks... ... ... ½ in. to	0	1
	Shales black, fissile, with thin streaks of fine grey sand ... ... 9 in. to	0	10
	Bone-bed or coprolite seam, soft white sand and quartz-pebbles: spines of *Nemacanthus filifer*, and *Hybodus*, sp.; teeth and scales of *Saurichthys acuminatus*, *Hybodus minor*, *H. reticulatus*, *Hybodus* sp., *Acrodus minimus*, *Sargodon tomicus*, *Ceratodus altus*, *Gyrolepis tenuistriata*, and various cestraciont palatal teeth; teeth and coprolites of *Ichthyosaurus platyodon*, *Ichthyosaurus* sp.., and other reptilian and piscine teeth, vertebræ, bones and coprolites ...	0	1
	Shales black, fissile, and earthy layers alternating ...	1	4
	Coprolite-seam, earthy; coprolites at wide intervals...	0	1
	Shales black, laminated, with occasional reptilian bones	1	3
Tea-green Marls (UPPER KEUPER).	Light-blue marls weathering yellowish-green and breaking up into cuboidal fragments; base not seen	20	0
	The Upper Rhætic marls were not seen *in situ*; but limestone nodules with *Estheriæ* were found in the overlying drift."		

A cutting near Plumtree, a mile further north on the same railway, still obscurely shows black Rhætic shale resting on Tea-green Marl and covered by drift. The shattered appearance of the shale, its outlying position relative to the main Rhætic mass, and the known disturbance of the beds by glacial agency in an adjacent section (*see* p. 77), render it uncertain whether the shale is *in situ* or has been glacially transported; but, in the latter case, it cannot have been removed far from its original position.

After leaving the railway the Rhætic is not again exposed until Keyworth Wolds are reached, where it appears at one spot to reach the surface. The position of its outcrop under the drift is doubtful, but a deep well 800 yds. S. of the fork in the road from Keyworth to Widmerpool passed through 47 ft. of boulder-clay directly into Tea-green Marl, thus proving the absence of the Rhætic at this point. When it again emerges from under the drift near North Lodge its feature can be followed down to the Fairham Brook, where the flinty limestone band, which is taken to mark its upper limit, is laid bare in the bed of the stream. Its position in the escarpment which sets in again a little W. of the brook is indicated by numerous small pits, where the flinty limestone has been dug in the past for use as macadam. A few feet of shale resting on the Tea-green Marl may be seen a mile S. of Bunny in the side of the Loughborough road, but apart from this section there are no exposures until the outcrop is followed round to Costock. Here, in a dry season, the flinty limestone and some other bands of similar limestone below it are visible in the bed of the stream near Field Farm. South of the stream the Rhætic is indicated only by the presence of several of the old limestone pits; and at Sheepwash

[1] "The Rhætics of Nottinghamshire." *Quart. Journ. Geol. Soc.*, vol. xxxviii., 1882, p. 454.

Brook it becomes covered by drift and does not again emerge before it is cut off by the Stanford Hall fault. It must, however, outcrop under the drift near Lings Farm, and running round the small valley of the brook from Rempstone, it forms part of the marked escarpment of Sutcliffe Hill. The place where it crosses King's Brook is marked by the presence of the flinty limestone in the stream-bed.

The Rhætic is never seen in the trough of the pair of faults running through Stanford Park, but its position is marked by the feature. The Normanton Hills fault throws its outcrop about 2 miles eastward, under the boulder-clay of the plateau. R. L. S.

The junction of the Rhætic with the Tea-green Marl was seen in Walton Brook, where a few inches of dark laminated shale rested on the green marl without the intervention of a bone-bed. On the southern slope of the valley of Walton Brook, the black shales were proved in a well, 500 yds. WSW. of Walton Church, and the base was seen resting on Tea-green Marl in the road-cutting on Barrow Hill a little further on, the dip being southward at 2°. Here a bone-bed was present.

The best sections of Rhætic in the southern area are at Barrow-upon-Soar, where the Rhætic escarpment, running along the NE. side of the Soar valley, is cut through by the Midland Railway, showing laminated lumpy shales resting on Tea-green Marl. By the roadside, 600 yds. SE. of Netherfield, grey shale with nodular limestone, representing part of the White Lias, was seen in a small quarry. The dip is here northward at 12°, owing to the proximity of the Barrow and Sileby faults. C. F. S.

CHAPTER IV.

LOWER LIAS.[1]

GENERAL ACCOUNT.

The outcrop of the Lower Lias occupies more than two-thirds of the area of the map, covering the whole of the Vale of Belvoir and swinging round southward, under a thick capping of boulder-clay, into the Wreak Valley, which, E. of Hoby, lies entirely within this formation. Its thickness in the district is estimated to be about 670 ft., calculating from the available data. This exceeds by about 30 ft. its proved thickness in a well-boring at Grantham,[2] 7 miles E. of the NE. corner of the map, but is 80 ft. less than its thickness farther southward, in Sheet 156.[3]

In the Vale of Belvoir, where its whole outcrop is exposed, the Lower Lias may be conveniently separated by lithological characters into the following subdivisions, in descending order, the lowest four of these having been already adopted in the official description of the country N. of the present map.[4]

F. Clays.
E. Belt of sandy shale and limestone.
D. Clays with thin limestones.
C. The Ferruginous Limestone Beds.
B. Clays below the Ferruginous Limestone.
A. The Hydraulic Limestone Series.

The relation of these subdivisions to the Ammonite-zones which form the basis of the palæontological classification of the Lower Lias is as follows :—

The zone of *Psiloceras planorbis* agrees very closely with the lowest subdivision A.

The combined zones of *Schlotheimia angulata* and *Coroniceras bucklandi*, which are not separately recognisable in this district, fall mainly within the subdivision B.

The zone of *Arnioceras semicostatum* includes the next three subdivisions, C, D and E, here assuming greater importance than in Yorkshire or in Gloucestershire. The remaining zones of *Oxynoticeras oxynotum*, *Echioceras raricostatum*, *Deroceras armatum*, *Uptonia jamesoni* and *Liparoceras capricornus*, so far as they may be present, are represented by the subdivision F, but little or no evidence for the zones of *Deroceras armatum* and *Echioceras raricostatum* is forthcoming in this district.

We will review the general characters of the subdivisions before dealing with the details of their outcrop.

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[1] By B. Smith, R. L. Sherlock, G. W. Lamplugh, W. Gibson, C. B. Wedd and C. Fox-Strangways.

[2] "Geology of the South-west part of Lincolnshire, etc." *Mem. Geol. Surv.*, 1885, p. 143.

[3] "Geology of the Country near Leicester." *Mem. Geol. Surv.*, 1903, p. 29.

[4] "Geology of the Country between Newark and Nottingham." *Mem. Geol. Surv.*, 1908, p. 59.

The succession is illustrated in the accompanying diagrammatic section, Fig. 3.

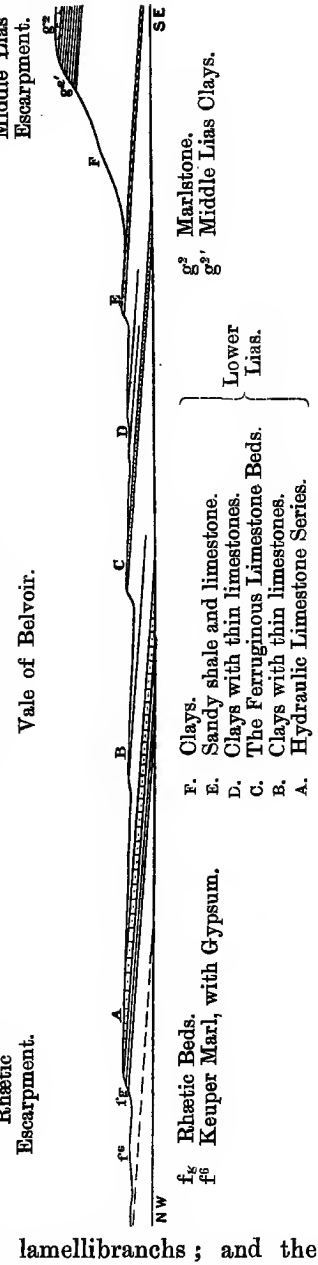


Fig. 3. GENERALIZED SECTION ACROSS THE LOWER LIAS OF THE VALE OF BELVOIR. (*B. Smith*).
Length of Section, about 6 Miles. Vertical Scale, = about 8 × horizontal.

Hydraulic Limestone Series (A).—These beds follow conformably upon the marls and limestones of the upper Rhætic, and consist of bluish-grey laminated shales with which are intercalated numerous bands of flaggy argillaceous limestone of paler tint. The series is extensively quarried for the manufacture of cement around Barrow-upon-Soar, Barnstone and Owthorpe, the workings affording excellent sections.

The outcrop of the series attains an exceptional width of nearly three miles between Cropwell Bishop and Kinoulton, owing partly to slight undulations combined with a very low average dip, and partly to the slope of the ground; but it contracts greatly along the strike in both directions from this tract, and is not usually more than ½ mile wide. The thickness of the series is about 20 ft. at Barnstone, and slightly less at Barrow-upon-Soar.

The valleys of the streams draining the Vale of Belvoir, which are usually shallow and ill-defined, become sharply marked and contracted where they cross these beds.

Fossils are not so abundant in the Hydraulic Limestone Series as in the higher zones, but the facilities for collecting afforded by the cement-stone workings are better than in any other part of the Lower Lias of the district. The most characteristic fossils are *Psiloceras planorbis*, with *Psiloceras johnstoni* and spines of echinoderms in the upper beds; a few lamellibranchs; and the occasional remains of saurians, fish, &c.

Clays below the Ferruginous Limestone (B).—Although the zone of *Psiloceras planorbis* corresponds closely with the Hydraulic Limestone Series, the latter is a lithological rather than a palæontological division, having a somewhat indefinite upper boundary,

and it is probable that a few thin nodular bands belonging to the next zone are here and there included with the 'stone-beds.' The overlying series of dark-blue shaly clays containing impersistent bands and nodules of limestone (the latter locally termed 'catheads') represents, however, the characteristic development of the Angulatus and Bucklandi Zones in the district, though in some parts of England it is at this horizon that the principal limestones of the Lower Lias are found.[1]

The lowermost portion of the subdivision is well seen in some of the cement-stone quarries near Barrow-upon-Soar, but with this exception the clays are very poorly exposed. The excavation for a new reservoir at the Holwell Ironworks, 2 miles W. of Melton Mowbray has, however, been made in the higher part of the subdivision, and we collected fossils characteristic of the above-mentioned zones from the spoil heaps at this place. The top of the subdivision is marked by the plentiful occurrence of *Gryphaea arcuata*, which affords aid in tracing its limits. Its total thickness is probably a little over 200 ft.

The next three lithological subdivisions, C, D and E, as previously mentioned, are united palæontologically into a single Ammonite-zone which includes about 150 ft. of calcareous clays or shales with several rock bands.

The Ferruginous Limestone Beds (C).—This belt, so important as a source of ironstone in North Lincolnshire[2], is recognizable only in the NE. part of the present map, where it is represented by a band of ferruginous limestone, seldom exceeding a foot in thickness, traceable from Barkestone to Harby, but then losing its distinguishing ferruginous character. Farther westward the base of the Semicostatus Zone is marked only by the above-mentioned abundance of *Gryphaea* below it.

Clays with thin limestones (D.).—Where the ferruginous band is present the clays above it contain several layers of fossiliferous limestone from 3 to 6 ins. in thickness, which form well-defined features, but these also become less and less conspicuous when traced south-westward, until their identity is lost. It is evident that all these thin limestones represent local conditions of sedimentation that prevailed over limited areas during the period, now in one place and now in another.

Belt of sandy shale and limestone (E.).—At or near the top of the Semicostatus Zone there occurs a more persistent sandy belt that appears to be a hitherto-unnoticed local peculiarity of the sequence. It enters the map N. of Belvoir, causing a slight feature which becomes more pronounced south-westward, and is practically continuous for 12 miles, up to the point near Upper Broughton where it disappears beneath the boulder-clay of the plateau. Its outcrop forms the sharp rise on which stand the villages of Long Clawson, Nether Broughton and Upper Broughton; and at these places the bed is over 10 ft. thick, consisting of sandy shale, with irregular lenticles of hard sandy limestone containing *Echioceras*

[1] H. B. Woodward; "Jurassic Rocks of Britain," vol. iii. *Mem. Geol. Surv.*, 1893, p. 36.

[2] "Geology of the Country around Lincoln." *Mem. Geol. Surv.*, 1888, p. 20.

raricostatum and *Arnioceras semicostatum*, with many lamellibranchs and a few brachiopods. Though hidden by boulder-clay W. of Upper Broughton, it is probably continued, in the shallow syncline of Lias, beneath the plateau until it sweeps round eastward on the S. side of the trough; for it is seen again in an exposure of Lias beneath the drift in the railway-cutting 850 yds. NW. of Holwell Ironworks.

Clays above the sandy belt (F.).—The clays of this upper portion of the Lower Lias are about 300 ft. thick. They are very poorly exposed in this map, so that our information respecting them is scanty. They generally weather into a stiff pale-blue clay subsoil, deficient in lime, and stained rustily with iron, indicating the presence of pyrites. They contain at wide intervals a few nodular lumps or slabs of fossiliferous limestone, as well as ferruginous 'boxstones' and other smaller ellipsoidal concretions. They were pierced by the shafts of the tunnel between Old Dalby and Grimston, and some of the characteristic fossils of the Oxynotus and Jamesoni Zones may still be collected from the spoil heaps at this place.

In the south-eastern corner of the map, around Stapleford Park, the railway-cuttings E. of Saxby station have yielded evidence of the presence of the Jamesoni and Capricornus Zones in the clays.

DETAILS.

In the following local description of the Lower Lias, we shall follow the course of the subdivisions separately along their outcrop from north-east to south-west, noting the principal exposures in the order of their occurrence.

The Hydraulic Limestones.—The best sections in the beds on the N. side of the Vale of Belvoir are afforded by the pits of the Barnstone Cement Works, which lie just upon and beyond the margin of the map, 1 mile ENE. of Langar. As the sections have been recently described in the memoir on Sheet 126 (p. 64), it is unnecessary to repeat the information.

In the vicinity of Langar, shales and limestones similar to those of the Barnstone pits are sparingly visible in several small exposures on the dip slope of the beds, and in abandoned pits in the wood ½ mile E. of Langar Church. They may also be seen in the banks of Stroom Dyke opposite the lodge of Langar Hall, and again at a point 500 yds. S. of Langar Church.

In the bed of a small stream tributary to Stroom Dyke W. of Newlands House, shales with well-bedded limestones containing fish remains are exposed at a depth of 4 ft. from the surface; and on its W. bank a pond was recently dug to a depth of 12 ft. in the series. Blocks of stone from another pond 200 yds. NW. of Newlands House yielded *Modiola minima?* J. Sow. and *Ostrea irregularis* Münst.

A newly-dug ditch, 5 ft. deep, in a field W. of the brook and 350 yards W. of Newlands House revealed thin platy limestones separated by shales; and at the E. end of the section, a band of nodular yellowish-grey limestone contained several poorly preserved Arietite ammonites. The beds apparently dipped gently southward beneath the platy beds, but shewed signs of disturbance. Stronger signs of disturbance were exhibited in a pond section 300 yds. SW. of the ditch, where a 4 in. bed of blue limestone in blue shaly clay dipped S. at 15°–20°. The limestone yielded *Modiola minima* J. Sow. and *Psiloceras planorbis* (J. Sow.).

Over the gently sloping low ground S. of the Rhætic escarpment between Langar and Colston Basset, thin beds of limestone are generally struck at a shallow depth, often at not more than 3 ft. from the surface.

Four layers of flaggy limestone alternating with shales, the whole about 16 ft. thick, are obscurely exposed in the steep slope of the Smite valley 400 yds. SE. of Edmondthorpe Lodge. Stone has been raised from several pits,

now overgrown, 500 to 600 yds. NNW. of the same place. The sharp accentuation of the valleys where they cross the Hydraulic Limestones is exemplified by the course of the River Smite N. and S. of Colston Basset. In this instance, however, the steepness of the valley is lost, S. of the village, before the stream leaves the outcrop of the stone beds, probably owing to the fact that several tributaries meet at or near this point, with a consequent broadening of the valley.

Near the confluence of its Owthorpe tributary with the Smite there are several sections showing flaggy and pale nodular limestones in the streams. The prevalent dip is either S. or SE. at a very low angle, but with occasional local disturbance. These disturbances lie almost in line with the small fault trending through Cotgrave Gorse and Owthorpe.

West of the Smite, the limestones form a gently sloping plain extending SE. to the ridge upon which Owthorpe is situated. Numerous old pits, more or less obliterated, near both sides of the canal as far S. as the Devil's Elbow, bear witness to the former extensive use of the rock for flagstone, building-stone, road-metal and lime-burning.

In one of these old quarries, 330 yds. SW. of the inn at Blue Hill, the limestone yielded *Modiola minima* J. Sow., *Ostrea liassica?* Strickl., *Pecten sp.*, *Pleuromya crowcombeia* Tate, relics of *Hybodus?* and *Cidaris*-spines.

Two quarries were being worked in this part of the outcrop in 1906. In the larger, on the E. side of the road, 300 yds. SSW. of the inn above-mentioned, the section was as follows, the names applied by the workmen to the different beds being given in brackets :—

	ft.
Soil with a few pebbles of sandstone	1
Friable limestone, weathered yellow, with *Psiloceras planorbis* ...	
Shales	
Limestone, weathered yellow, with ½ in. 'spine-bed' [Rust] at top. *Psil. planorbis*, &c.	
Shales	6
Pale nodular limestone, with *Psil. planorbis*	
Shales	
Pale nodular limestone Shales [Twin floors] ... ... Pale nodular limestone	
Shales	2
Blue wavy-banded limestone [Thick floor] in two beds, with *Ichthyosaurus*	2
	about 11 ft.

Water-level was reached at the above depth, but we were informed that the section continued as under :—

Blue limestone [Cap], with *Plesiosaurus.*
Blue flaggy limestone [Slab].
do. [Bottom].

Besides Saurian remains the beds contained :—

Cidaris edwardsi *Wright.*	Pecten sp.
Lima gigantea (*J. Sow.*)	Psiloceras johnstoni? (*J. Sow.*)
Modiola minima *J. Sow.*	Psiloceras planorbis (*J. Sow.*)

The 'spine-bed,' distinguished by the abundance of echinoid-spines, is a well-marked horizon in this district, traceable over about 2 sq. miles and ranging up to 1 inch in thickness.

The blue wavy-banded limestones, which contain more crystalline calcite than the other beds, furnish the best flagstones. In this quarry the maximum size of the flagstones raised is 3 × 4 ft., but larger ones could be obtained if required.

The second quarry is situated on the W. side of the road, 550 yds. NE. of Owthorpe Church. It shows a section almost identical with that above described ; the correspondence being so close that the gentle fall of the surface between the two quarries is evidently paralleled by the average dip of the beds, though the dip as measured in the quarries seemed to be rather higher than this, being probably affected by slight undulations.

The slight ridge upon which Owthorpe stands is due to the upthrow of the Hydraulic Limestones by the previously-mentioned fault trending SE. from Cotgrave Gorse. The repetition of the dip-slope thus caused, together with the lessened and undulatory dip on both sides of the fault, explains the great width of the outcrop in this quarter. The upthrow must bring the Rhætic Beds very near the surface, for the deep boring upon the ridge at Owthorpe proved that only 12 ft. 6 ins. of the Hydraulic Limestone was present.[1]

Several small exposures of the limestones in ponds, etc., occur on the dip-slope S. of Owthorpe; and a quarry W. of the road ¾ mile N. of Kinoulton Church exposed six beds of stone, yielding *Lima acuticosta?* Münst., *Lima gigantea* (J. Sow.), and *Ostrea liassica*, Strickl.

In a large disused quarry about 100 yds. west of the Devil's Elbow a very similar section to that of the above-described stone-workings near Blue Hill was revealed, but with the beds up to a slightly higher horizon. The dip here is northward at 6°, indicating a local undulation or disturbance.

Sixteen bands of stone are exposed in this section, which is 16 ft. deep. At a depth of 13 ft. is a bed of hard limestone 5½ ins. thick, with a 'spine-bed' ½ in. thick at its top. *Psiloceras planorbis* occurs in this bed and also in the beds above and below it, with *Psil. johnstoni?* in the upper beds. At the bottom of the section there are two bands of grey limestone with a shale parting, having a united thickness of 7 ins., which may represent the 'Twin floors' of the previous section.

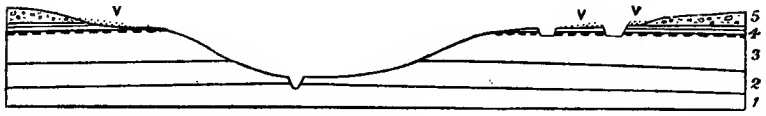
The dissected plateau of boulder-clay, locally known as 'The Wolds,' which bounds the Vale of Belvoir on the west, greatly obscures the westerly outcrop of the Hydraulic Limestones. They form, however, a sloping shelf along the N. front of the Cropwell Wolds, and have been quarried in several old pits upon both sides of the road N. of Mount Pleasant and along the Foss Way in the neighbourhood of Cotgrave Gorse. Some of these pits have evidently been carried below the base of the Hydraulic Limestones, like the small quarry on the NE. side of Cotgrave Gorse, described in the previous chapter (p. 19).

The same shelf of Lower Lias is again seen under Wolds Hill and for a few hundred yards further, until it is overlapped by the boulder-clay; and here again it has been the site of many excavations for stone.

Similar excavations occur on both sides of the valley S. of Wolds Hill and also in the valley W. of Wynnstay Wood. A section exposed 440 yds. S. of the bifurcation of the roads at Wolds Hill is very similar to that seen in the Devil's Elbow quarry. It shows a local dip of 4° to the east.

The profile of the outcrop on the flanks of these valleys is shown in Fig. 4. The shelf is often partly covered by a downwash of drift, but its

Fig. 4.—Diagrammatic Section showing the double feature marking the Boulder Clay and Rhætic Escarpments. (*B. Smith*).



1. Red Keuper Marl. 2. Tea-green Marl. 4. Rhætic Beds with Limestone. 4. Lower Lias Limestones. 5. Boulder Clay. V Rainwash.

features are so unmistakable that the mapping of the geological boundaries is a comparatively easy matter, except at the heads of the valleys, where the Rhætic beds do not reach the surface and where the Lias is almost swamped by the stony downwash.

B. S.

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[1] "Geology of SW. pt. of Lincolnshire, etc." *Mem. Geol. Surv.* 1885, p. 150. In the revised account of this boring published in "Geology of . . . Newark and Nottingham." (Sheet 126), *ibid.*, 1908, p. 106, the 'White Lias' (Upper Rhætic) has been erroneously included with the Lias.

On Plumtree Wolds there are two large old excavations in the Hydraulic Limestone Series, one of these, on the E. side of the plantation still showing obscurely about 20 ft. of blue-grey sandy shales with a 4-in. band of limestone. Between Plumtree Wolds and Keyworth Wolds the outcrop is concealed by drift, but was seen in the Stanton railway-tunnel (*see* p. 78). It reappears in the valley of the small stream S. of Stanton Lodge, but is obscured by downwash, excepting where excavated for the limestones. The largest of these old pits, 400 yds. NE. of North Lodge, shows about 7 ft. of drift resting on about 13 ft. of shaly clay with thin flaggy bands of fossiliferous limestone. The outcrop in the valley of the Fairham Brook is also obscured by downwash and alluvium, but flaggy limestones are exposed in the bed of the stream below the weirs at Widmerpool.

Drift covers most of the outcrop between Widmerpool and Wysall, but the Lias usually just emerges at the crest of the Rhætic escarpment, and the stone-beds have been quarried in several small pits. It may also be seen *in situ* in the road near Longcliffe Farm.

The covering of drift extends for only a few hundred yards W. of Wysall, and then ends off, exposing a considerable area of bare Lias which runs westward in a long spur through the East Leake Hills. Probably the Lias over the greater part of this area is only a few feet thick; the dip of the beds corresponding to the gentle slope of the ground. The soil is a stiff brown clay, derived from Lias shales, with flaggy limestones exposed in small pits and ditches at a depth of 2 or 3 ft. At East Leake Hills, the Lias has been protected by an isolated patch of gravelly drift, and is probably thicker. A small disused pit ⅛ mile W. of East Leake Hills shows about 6 ft. of thinly-bedded crystalline limestone, with oysters, *Modiola*, &c., intercalated with decomposed shale.

The outlier of Lias NW. of East Leake, of which only the E. end falls within the present map, shows similar sections in numerous small pits on Crow Wood Hill.

South of the Costock valley, the Lias is seen only along the margin of the denuded plateau of drift. Two small disused quarries on the highroad NE. of Glebe Farm, Costock, show thin flaggy limestones separated by shales; and a better section is laid bare in the bed of the adjacent stream where it touches the road.

Two miles farther S., the Lias emerges from under the drift along the small deep valley of King's Brook, but no clear exposures were seen on the Rempstone side of the valley.

On the opposite or S. side, however, the highroad at the Windmill, near Hoton, has a cutting, now obscured by vegetation, through about 15 ft. of Lias dipping slightly S. On both sides of this road, small pits give indications of Lias; and ¼ mile W. of the Windmill an old quarry, about 30 ft. deep, in shale with flaggy bands of fossiliferous crystalline limestone, seems to have been carried down to the top of Rhætic, judging from the occurrence of fragments of the smooth compact limestone forming the top of that series.

There are good exposures of the Lower Lias just beyond the W. margin of the map, in Sheet 141, both in the railway-cutting at Normanton Hills (*see* "Geology of Derby, etc., and Loughborough," p. 37) and in adjacent cement-stone quarries. In this quarter an old quarry on the S. side of the road from Ashby-de-la-Zouch, 400 yds. S. of White Hill Farm, which lies just within the present map, shows from 25 to 30 ft. of bluish shale, with two thin bands of limestone.

R. L. S.

The Lower Lias of the Soar valley in the neighbourhood of Barrow, and of the Wreak Valley as far east as Kirby Bellars was mapped by Mr. C. Fox-Strangways, and was described by him, along with the ground adjacent to the south, in his memoir on Sheet 156,[1] from which the following account is quoted:—

"The lower portion of the Lias is best seen . . . . in the neighbourhood of Barrow, where the numerous pits that are constantly being worked for these valuable limestone bands afford an interesting series of sections. These pits, being opened nearly on the same horizon, are very similar to one another, and show the great uniformity there is in the character and thickness of the beds, the variations observed in them arising chiefly from their difference in position

[1] "The Geology of the Country near Leicester." *Mem. Geol. Surv.*, 1903, pp. 22–23.

and depth. The following section, kindly supplied by Mr. Montagu Browne, gives a good idea of the general character of these beds at Barrow :—

General Section of the lime pits at Barrow.[1]

Lithological character and local name.	Thickness.	Organic Remains.
	Ft. in.	
Soil and Drift	3 0	
Argillaceous shale	5 0	*Schlotheimia angulata.*
Limestone (Bank Hurs) ...	0 3	*Cidaris edwardsi. Schlotheimia catenata.*
Shale (The Roak)	16 0	Plesiosaurian remains.
Limestone (Rummels)	0 10	Angulata zone. *Lima. Pecten.*
Shale (Rummels Calf)	4 0	*Psiloceras johnstoni*, very abundant.
Limestone (First floor)	0 6	*Psiloceras planorbis*, rare.
Shale (Second floor Calf) ...	1 0	Ichthyosaurian remains. Various Fishes and Saurians.
Limestone (Second floor) ...	0 6	*Palæotermes ellisi.*
Shale (Hur Calf)	0 9	
Limestone (Hurs)	0 6	*Lima.*
Shale (Hog Calf)	1 6	*Dapedius.*
Limestone (Hog and Second Hog, sometimes including a shale of 2 inches)	0 8	*Psiloceras planorbis. Dapedius.*
Shale (Bottom-floor Calf) ...	0 6	
Limestone (Bottom floor) ...	0 6	*Dapedius* and various Fishes.
Shale (Good-for-nothing Calf) ...	1 0	Various Saurians, Fishes, and Invertebrates.
Limestone (Good for nothing) ...	0 4	*Psiloceras planorbis*, abundant, and various Fishes.
Shale (Four-foot Calf)	2 6	Various Saurian remains and Fishes.
Limestone (Four foot)	1 0	*Psiloceras planorbis* commences.
Shale	Rhætic beds, not worked.	
Limestone (Black Rummels)		
Shale		
Limestone (White Hurs)		
Shale		

" Beds of limestone and shale are frequently exposed along the stream course between Sileby and Seagrave, but the strata are so much disturbed along this valley that the general sequence of the rocks is not very clear ; they appear, however, for the most part to belong to this zone. The limestones were worked in former times at Seagrave, but the pits have long been closed.

" Along the valley of the Wreak they again come out in the small streams near Thrussington and Hoby, and a strong band of limestone, with *Am.* [*Psiloceras*] *planorbis*, is seen in the railway cutting just north of Rotherby. [Prof.] Judd mentions that traces of the Fish and Insect Limestones, lower part of the zone of *A. planorbis*, were found in the railway cutting at Kirby,[2] which seems to show that if the beds are not repeated by faults they must be lying nearly flat along this part of the valley. This section is now, unfortunately, entirely obscured ; and, not knowing of the above observation at the time, there was considerable difficulty in arriving at a conclusion whether it was cut in solid strata at all."

C. F. S.

[1] " Compare section by Harrison, Geology of Leicestershire and Rutland, p. 37."
[2] " Geology of Rutland (Survey Memoir), p. 58,"

Owing to the extensive scale of the cement industry at Barrow, the quarries, usually opened on the valley-slopes just above the outcrop of the main group of limestones, are rapidly worked back until the overburden of shale and drift becomes too thick for profitable removal. In some cases the cement-rock is then gained from levels or galleries driven underground, but more often the working, already partly filled in with waste, is abandoned and smoothed over so that the site becomes again available for agriculture. In this manner a large proportion of the ground upon the outcrop of the Hydraulic Limestones around Barrow has been worked over piecemeal, the position of the open sections being never constant for long. Hence most of the pits that were being worked when the ground was surveyed by Mr. Fox-Strangways are now obliterated. When the district was revisited in 1906 by Mr. Lamplugh the chief operations were the underground galleries in the neighbourhood of the cement manufactory, ½ mile ESE. of Barrow; a new pit, 30 ft. deep, on the N. side of the road 900 yds. E. of Barrow Church; and an extension of an older quarry at Cream Lodge in the valley of the Fishpool Brook, 1 mile NE. of Barrow. In 1908, the new pit was still in operation, but the Cream Lodge excavation was in abeyance and partly obliterated.

When fully exposed the last-mentioned section was particularly interesting as it showed a sharp anticlinal fold in the strata, the disturbance appearing to have its axis along the direction of the valley-bottom and the beds resuming their approximate horizontality at the N. edge of the excavation; a photograph taken by Mr. F. R. Rowley in 1900, at the E. end of the section, at right angles to the axis of the fold, is reproduced on Plate II. The disturbance has been accentuated by some superficial agency, probably glacial, as there were subsidiary crumplings in the top beds which died out downward; and patches of sandy gravel were in places implicated in these minor folds (*see* p. 85; also Fig. 14, p. 55, in "Geology of the Country near Leicester," *Mem. Geol. Surv.*, 1903.)

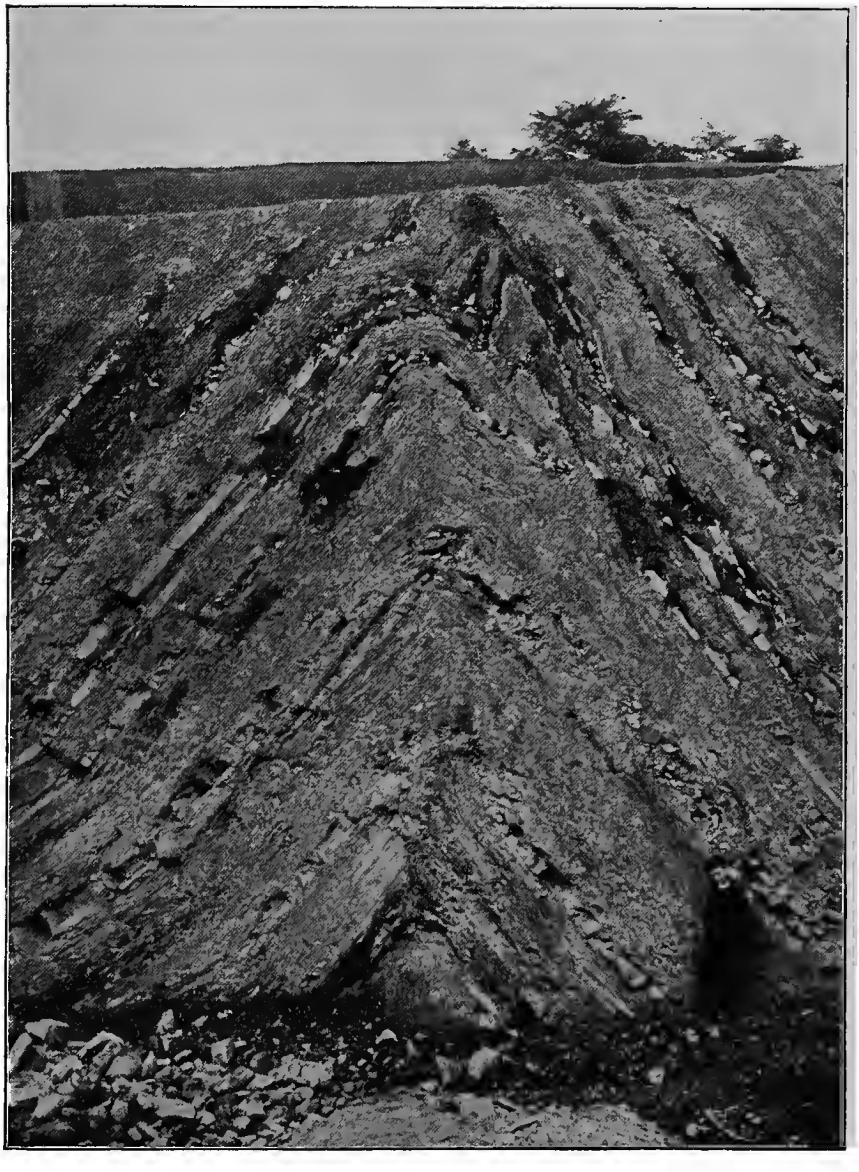
The pits of Barrow have long been famous for their reptilian and fish remains. Collections of these fossils are to be found in many museums, including the Dublin Museum, British Museum (Natural History), Sedgwick Museum at Cambridge, and the local museums at Leicester, Nottingham, etc. A list of the species, with details respecting many of the specimens, is contained in Mr. Montagu Browne's "Vertebrate Animals of Leicestershire and Rutland" (Leicester, 1889), pp. 173–203. Other references to the literature of the subject will be found in the bibliography at the end of the present memoir, p. 108.

The further extension of the Hydraulic Limestones in an easterly direction has been proved by well-sections at Asfordby Place and at the Great Northern Railway Station, Melton Mowbray (p. 106). G. W. L.

Clays below the Ferruginous Limestone (B.).—In the triangular tract between Langar, Barkstone and Hose the sole important exposure of the Lower Lias is that of the Barnstone cement-stone quarries, and the higher beds intervening between the Planorbis Zone and the base of the Semicostatus Zone are seen only in a few shallow sections in Rundle Beck and in ponds when the water is low. Where not covered by a sprinkling of flinty drift, the surface of these clays weathers brown to a depth of 1 or 2 ft., passing imperceptibly downward into bluish clay in which *Gryphaea* is often abundant. In the banks of Rundle Beck N. of Granby Gap four bands of pale earthy limestone are seen, from 5 to 8 ins. thick. These limestones were traceable for some distance north-eastward in Sheet 126, but could not be detected over the flat land to the SW. of Granby Gap.

During the previous survey, a small collection was obtained from these beds at a spot 3 furlongs SW. of Redmile, just within the limits of the present map. The fossils preserved in the Palaeontological Department of the Survey from this locality include *Gryphaea arcuata* Lam., *Lima* (*Radula*) *duplicata* (J. de C. Sow.), *Lima hettangiensis* Terq., *Modiola scalprum* J. Sow., *Pecten sp.*, *Pinna spathulata* Tate, and *Pteria* (*Oxytoma*) ?. W. G.

West of the flat referred to above a fairly continuous feature running SW. from Newlands House through Kaye Wood to Kinoulton marks the oncoming of the belt of clays with impersistent bands of nodular limestone. This feature is most pronounced in the neighbourhood of Kinoulton, the long straggling



QUARRY NEAR CREAM LODGE 1 MILE NE. OF BARROW-UPON-SOAR.
Contortion in the Hydraulic Limestone Series of the Lower Lias (*see* p. 30).
From a photograph, in 1901, by Mr. F. R. Rowley.

village being situated upon its brow. Numerous small pond-sections occur in this clayey belt, revealing occasional layers of nodular limestone. The clays form a tract of stiff cold soil, in which the water-supply is generally deficient, as the yield from wells sunk into the thin beds of limestone is scanty, and often poor in quality.

Although the 'cathead' nodules are sometimes fossiliferous, the fauna obtained from these beds is very limited. *Cardinia listeri* (J. Sow.) var. *hybrida ?* (J. Sow.) and *Astarte camertonensis* Moore, were abundant in the clay from a pond at the farmstead about ½ m. SE. of Newlands House. The well at the house 500 yds. SSE. of Langar Grange pierced a 6 in. band of limestone with *Gryphaea arcuata* at 42 ft. from the surface. The wells at Hills Farm, Home Farm, Rose's Farm, and Colstonhills Farm all proved occasional thin bands of stone yielding many crinoid columnals, and that at Hills Farm probably reached the Hydraulic Limestones. Stone was formerly dug in this neighbourhood, traces of the old quarries being still visible in a field ¼ m. ENE. of Rose's Farm. The site of an abandoned brickyard is also marked by a reedy pit on the N. side of the canal at Hose Gorse. A well, sunk in 1906, at Canal Farm pierced several beds of stone with *Gryphaea arcuata*, and the fields around Kinoulton Grange have the same fossil scattered over them in profusion. The numerous ponds between Canal Farm and Hickling yielded *Gresslya sp.*, *Gryphaea* cf. *arcuata* Lam., *Lima hettangiensis* Terq. and *Unicardium sp.* and crinoid plates and joints. In the brook N. of Hickling (Dalby Brook of the 6 in. map) there are small sections showing pale nodular limestones in blue clay with race, containing fragments of crinoids, echinoid spines, ostreas, pectens, &c.; and similar sections occur here and there W. and SW. of Hickling. On the dip-slope S. of Kinoulton the ponds expose several layers of stone—creamy, rubbly, and platy, which resemble lithologically some of the Hydraulic Limestones. At the W. end of the village there are traces of stone pits, and an old brickyard is situated by the canal side 250 yds. S. of the Vicarage. The bricks appear to have been made from the alluvium of a small stream which runs through the yard, as well as from the Lias clay.

Clays and limestones of the same belt form the E. slopes fringing the boulder-clay plateau from Hickling Standard northward to Cropwell Wolds, and disappear westward beneath the boulder-clay. They are exposed in many small ditch and pond sections, showing the usual characters of the series. Under The Trussel on Hickling Standard the Lias clays contain gryphaeas in abundance, thus continuing in this direction the gryphaea-belt traceable from near Plungar.

Between Hickling Pasture and Kinoulton Gorse a series of shelves or terraces may be traced, following the contours of the hill-slopes. The line of the parish boundary between the Moat and the summit of the hill crosses four of these features which are doubtless due to the beds of limestone, though the shelves have probably been accentuated by soil-creep during the processes of agriculture.

Limestone from a pond beside the Fossway, 330 yds. N. of Owthorpe Lodge, contained *Lima hettangiensis* Terq. and *Schlotheimia ?*; and the following fossils were obtained from stone thrown from a newly-cut ditch upon the E. side of a plantation, 220 yds. N. of Mt. Pleasant, Cropwell Wolds:—*Cardinia ?*, *Lima gigantea* (J. Sow.), *Lima hettangiensis* Terq., *Pecten sp.* [? n. sp.]. Indeterminable fragments of ammonites and a nautilus were also found. The shell-fragments in these beds are often iridescent.

On the plateau of the Wolds the Lias is hidden; but it emerges from beneath the drift in most of the deeply-cut valleys draining westward, though usually so much obscured by downwash that it is difficult to recognize the precise horizon where the outcrop includes beds higher than the Hydraulic Limestones (*see* p. 27 and Fig. 4). Due W. of Widmerpool Station a small brook (Roehoe Brook of the 6 in. map) exposes clays above the last-mentioned group, containing peculiarly weathered slabs and 'catheads' of limestone. Clays and limestones of approximately the same horizon have also been proved at various points in the valley of the Fairham Brook and its branches above Widmerpool. A new well on the parish boundary 440 yds. S. of South Lodge pierced 12 ft. of blue clay with a 4 in. bed of soft grey limestone, containing pentacrinites. At the site of an abandoned brickyard in the field E. of the Fossway Railway Bridge, 'catheads' of limestone with the usual small fossils are still to be seen, and similar concretions were turned out of a pond 250 yds. S. of the bridge. East of this place the Lias clays extend up a dry valley, until they reach the level of the plateau N. of Hickling Pasture and unite with the Lias outcrop of the eastern

slope, thus breaking the continuity of the capping of boulder-clay, without markedly altering the shape of the plateau. The presence of the Lias in this position shows the uneven character of its surface beneath the drift.

South of the Widmerpool valleys, there are very few exposures of the beds above the Hydraulic Limestones. A small pit ¼ m. SW. of Wymeswold Church, yielding fragments of limestone with traces of Arietite ammonites, is probably within this division; and the lower part of the group is frequently exposed in the cement-stone workings around Barrow-upon-Soar mentioned above (p. 29).

Farther eastward, fossils characteristic of the Angulatus and higher zones were found in the excavation for the Holwell Ironworks Reservoir previously referred to; the list of species is given subsequently (p. 35). B. S.

Ferruginous Limestone (C), *Clays with thin limestones* (D) *and Belt of sandy shale and limestone* (E). = (Semicostatus-*Beds*).—The ferruginous limestone, forming the lowest member of this group, caps the conspicuous ridge extending from Barkestone to Harby. The feature then becomes obscure, and dies out W. of Hose, the limestone at the same time losing its ferruginous character and individuality. The rock-band has often been removed from the brow of the ridge by denudation so that its present outcrop may lie some distance back on the dip-slope. It seldom exceeds 1 ft. in thickness and frequently measures but a few inches. It is succeeded by about 120 ft. of blue shales with thin beds of limestone, all of which fall within the zone of *Arnioceras semicostatum*.

There are very few exposures of the ironstone in the district, the best being that seen in the banks of a pool near the Manor Farm, Barkestone, which showed 8 ins. of the ferruginous rock resting on brown clay with *Gryphaea*. During the original survey it was exposed in the cutting of the Bottesford Branch railway between Stathern Junction and the Grantham Canal. At the S. end of the cutting the ironstone consisted of an upper bed 18 ins. thick, separated by 2 ft. of blue clay from a lower ferruginous limestone 6 in. thick. Further N., in the deeper part of the cutting, the following section was obtained.[1]

	ft.
Clay soil and yellowish clay	2
Blue laminated clay	3
Calcareous layer, full of *Gryphaea*	1
Grey shaly clay	2
Compact brown ironstone, full of fossils	1
Loose rubbly stone, with fossils	0½
Dark blue clay, with large *Gryphaea*	2
Grey ferruginous limestone, full of *Gryphaea*	0½
Blue shaly clay, seen for	2
	14

The following species from the higher beds in the cutting are represented in the original collection preserved in the Palaeontological Department of the Survey:—

Microthyris perforata? (*Piette*)
Rhynchonella calcicosta (*Quenst.*)
„ tetrahedra (*J. Sow.*)
„ variabilis? (*Schloth.*)
Cardinia concinna (*J. Sow.*)
„ listeri (*J. Sow.*)
Cardium sp.
Corbicella?
Gryphaea arcuata *Lam.*
„ cymbium? *Lam.*
Lima gigantea (*J. Sow.*)
„ pectinoides (*J. Sow.*)
Modiola scalprum *J. Sow*
Pecten liasianus *Nyst*
„ textorius *Schloth.*
„ sp.
Pinna sp.
Pteria (Oxytoma) inaequivalvis (*J. Sow.*)
Amberleya chapuisi? (*Terq. & Piette*)
„ elegans (*Münst.*)
„ sp.
Cryptaenia consobrina? *Tate*
Pleurotomaria *near to* anglica (*J. Sow.*)
Arnioceras semicostatum (*Young & Bird*)
Acrodus nobilis *Ag.*

[1] "Geology of the South-west part of Lincolnshire, etc." *Mem. Geol. Surv.*, 1885, p. 30.

Mr. Jukes-Browne[1] remarks that "the [Gryphaea] shells are all irregular, with badly formed umbones, and are very different from the regular incurved forms found elsewhere in the Lias Clays." The same characters are noticeable in the specimens of this shell which occur in profusion at the surface along the outcrop of the band between the railway cutting and Harby village. where the limestone ceases to be ferruginous.

The bands of fossiliferous limestone, from 3 to 6 ins. in thickness and rarely attaining 1 ft., in the shales above the ironstone, give rise to low but readily traceable features to the SE. of Barkestone and Plungar. These become, however, less conspicuous when followed south-westward, so that their identity is lost between Harby and Hose, where only one of the lower bands has been noticed. As in the case of the Ferruginous Limestone, though the outcrop of the hard bands occasionally coincides with the crest of the feature, it more frequently creeps some distance down the dip-slope. Among the fossils obtained from the lowest of these limestone bands in a pond 300 yds. NE. of Barkestone Vicarage were the following (determined and preserved in the Palaeont. Dept. of the Survey) :—*Cardinia listeri* (J. Sow.), var. *hybrida* (J. Sow.), *Lima gigantea* (J. Sow.), *Lima* cf. *pectinoides* (J. Sow.), *Aegoceras ?* and *Echioceras raricostatum ?* (Ziet.)

The limestone next in upward succession contains few fossils, but rests on a blue clay full of *Gryphaea.*

The next higher band is well seen in a gutter by the roadside where the small stream from Terrace Hills crosses the main road from Harby to Redmile. Fossils are abundant, comprising, amongst others, *Lima gigantea* (J. Sow.), *Nuculana* cf. *quenstedti* Tate, and *Pecten* (*Chlamys*) *thiollieri ?* Mart.

To which of these bands the two thin limestones seen at Harby and Hose correspond cannot be determined. In the stream S. of Hose village *Cardium* and *Pecten* are abundant, and the latter fossil occurs in profusion in a limestone a little higher in position, seen in a pond 130 yds. SSW. of Harby Church.

W. G.

The low-lying tract between Hose and Long Clawson, although devoid of drift, affords scarcely any exposures. Hose Villa stands upon a low eminence evidently produced by a thin bed of limestone cropping out along its crest and making a long south-easterly dip-slope. Material apparently excavated from a pond on the top of this rise consisted of slabs of blue laminated shelly limestone with *Arnioceras semicostatum* (Young & Bird) (fairly abundant), *Pteria*, *Pecten* and a small *Rhynchonella.* The beds seem to belong to the upper part of the Semicostatus Zone.

C. B. W.

The disappearance of the Ferruginous Limestone renders it difficult to trace the base of the group farther westward. A strike-feature about 1 mile N. of Long Clawson, running SSW. to the River Smite, probably denotes a hard bed, but no exposure was found along it. A feature again appears between the Smite and Dalby Brook. A pond on the dip-slope 400 yds. N. of Nether Broughton Church exposes a shaly ferruginous band with abundant *Gryphaea* and a bed of dark blue limestone 2 to 4 in. thick, with *Echioceras raricostatum ?* (Ziet.), *Gryphaea*, *Lima*, *Pecten* and a belemnite. A lower feature in the same locality is probably due to a nodular limestone from which, again, *Echioceras raricostatum* ? (Ziet.) was obtained. West of the brook the higher limestone forms a feature at the bends in the road below Muxlow Hill ; and E. of the road, at a slightly lower level, a 6-in. bed of stone, seen in a pond, yielded *Rhynchonella calcicosta ?* (Quenst.), *Gryphaea sp.*, *Pecten* cf. *acuticosta* Lam., *Pecten* (*Chlamys*) *thiollièri ?* Mart. and *Pecten sp.*, while a nodule from the blue shales upon the opposite side of the road contained *Arnioceras semicostatum* (Young & Bird). The feature due to this thin stone-band can be traced in the valleys W. of Muxlow Hill, and it here seems to mark the lower limit of a series of blue shaly clays which become rusty when weathered.

The upper part of this series is seen in the floor of the Muxlow Hill brick-yards, and consists of grey-blue micaceous and sandy shales, with small crushed lamellibranchs, pale limestone-nodules, and ellipsoidal ferruginous concretions around which the shales assume a red tint.

B. S.

The Sandy Shale with limestone (E) which occurs at or near the top of the Semicostatus Zone forms, in the western part of the Vale of Belvoir, the best

[1] *Op. cit.*, p. 29.

defined horizon within the area of the Lower Lias, possessing distinctive lithological characters and also rising in a strong feature. In the eastern part of the map, however, NE. of Hose, it is much less conspicuous, though still traceable by a slight rise in the ground and by the loamy character of the soil along its outcrop. In this part it is very sparingly exposed, and is first clearly seen in pond-sections near Mount Pleasant, SW. of Hose. It is probably represented by the band of grey sandy fossiliferous limestone, 4 in. thick, which crops out among blue shaly clay in a pond 200 yds. S. of the Hall, NE. of Long Clawson.

At the village of Long Clawson it rises in a low ridge or escarpment, its sandy limestone and sandy shale being best exposed in two ponds on the dip-slope at the SE. end of the village, in which *Modiola hillana* J. Sow., *Rhynchonella*, *Gryphaea*, *Cardinia* and a belemnite were noticed. In the lane leading S. to Long Clawson Windmill, and in the adjacent stream-gutter, flaggy calcareous sandstone and sandy shale with calcareous lenticles are exposed. The same band also supports the gently sloping shelf of loamy-clay soil at the W. end of Long Clawson.

The sandy beds are still better seen in the Nether Broughton platform, on which they weather into a rusty stiff loam. Numerous pond sections in and about the village expose 2 to 4 feet of grey calcareous sand-rock weathering yellowish or rustily, and the beds have been dug in an old shallow pit in the middle of the village. They contain here *Terebratula*, *Pecten*, *Belemnites*, along with tubular casts and small oval brown nodules; among the fossils collected is *Microthyris perforata?* (Piette).

G. W. L.

Near Upper Broughton the sandy beds form a rather bold and much-dissected shelf protruding from beneath the boulder-clay and dipping gently to the SE. The best exposure here is in the Muxlow Hill brickyard, where the following section was measured in the newer pit on the E. side of the road :—

	ft.	ins.
Soil and sandy clay with occasional pebbles	1	6
Band of flaggy micaceous sand rock-stained with manganese	0	6
Pale blue clayey sands full of little chips of sandrock stained with manganese	2	6
Bed of more or less compact sand-rock with red and black staining, much weathered	1	0
Blue to red clayey sands	3	6
resting on		
	9	0

Blue laminated slightly sandy shales, weathering rustily.

At the western end of this section blue clay comes in above the top sand-rock. The lower clayey sands contain many ellipsoidal ferruginous concretions.

In the old pit on the W. side of the road a hard blue-hearted sand-rock which stands out from the overgrown working-face appears to be the upper bed of the above section.

In microscopic section the rock is seen to be a fine-grained calcareous grit. The quartz grains are small, even and angular, among which are mingled a few flakes of white mica, chips of calcite, and fossil-fragments. The whole is set in a calcareous cement.

The rock-bands and intercalated clays of these pits yielded the following fossils, which are preserved in the Survey Collection :—

Cardinia sp.
Gryphaea cymbium *Lam.*
Hippopodium ponderosum *J. Sow.*
Lima gigantea (*J. Sow.*)
Modiola scalprum *J. Sow.*
Ostrea irregularis *Münst.*
Ostrea sp.
Pteria (Oxytoma) inaequivalvis (*J. Sow.*).
Pecten *cf.* acuticosta *Lam.*
Pecten *cf.* liasianus *Nyst*
„ (Chlamys) texturatus? *Münst.*
„ (Chlamys) textorius *Schloth.*
„ sp.
Pholadomya sp.
Pinna sp.
Arnioceras semicostatum (*Young & Bird*)
Belemnites acutus? *Mill.*

Another brickyard in the sandy beds was formerly worked at the west end of Upper Broughton village. On or near its site there are many small exposures in the calcareous sandstone from which *Gryphaea* cf. *cymbium* Lam., *Pecten sp.* and fragments of *Unicardium?* and *Rhynchonella* were obtained.

The most westerly exposure of the sandy belt is the much-obscured section in the railway cutting at Upper Broughton Station which shows the sandy beds apparently dipping at about 1° to SE, but the true dip is probably more southerly.

There is evidence that the belt maintains its distinctive character beneath the drift and swings round the shallow syncline to the southward, for the sandy beds emerge again, 4½ miles SSW. of the Broughton section, in another railway cutting 500 yds. WNW. of the Holwell Ironworks.

At this place, an old quarry in the cutting shows, obscurely, blue shaly clay capped by a few feet of sandy shale with an irregular calcareous rock-band containing a few fossils. The clays yielded an ammonite, cf. *Echioceras raricostatum* (Ziet.); and among other fossils obtained here chiefly from the sandy beds are :—*Cardinia listeri* (J. Sow.), var. *hybrida?* (J. Sow.), *Gryphaea cymbium* Lam., *Gryphaea sp.*, *Modiola sp.*, *Pleuromya sp.*, *Belemnites* cf. *acutus* Mill.

The excavation for the new reservoir 200 yds. NW. of Holwell Ironworks, previously referred to (p. 32) appears to have commenced somewhat above the base of the Semicostatus Zone, though lying mainly in lower beds. The spoil heaps furnished the following fossils :—

Pentacrinus columnal	Lucina?
Ditrupa sp.	Pecten sp.
Microthyris perforata (*Piette*)	Arnioceras semicostatum (*Young & Bird*)
Rhynchonella plicatissima? (*Quenst.*)	Echioceras raricostatum? (*Ziet.*)
Gryphaea cymbium *Lam.*	*Cf.* Schlotheimia angulata (*Schloth.*)
Lima?	

B. S.

From the southern margin of the map in the neighbourhood of Melton Mowbray northward to the outcrop of the Middle Lias Marlstone, the Lower Lias is concealed by drift and alluvium. Limestone is said to have been exposed in the Asfordby Road near the W. end of Egerton Park, Melton Mowbray; but the only important evidence of the solid geology of that neighbourhood is afforded by a boring for water about 200 yds. W. of the Great Northern Station, close to the north side of the railway and to the Scalford Road.[1]

In the valley of the Eye east of Melton Mowbray the drift thins out rapidly on the low ground, and a considerable area of Lower Lias is free from any covering, though rarely exposed in section. In passing eastward up the valley we first meet with evidence of Lower Lias in the dark shaly clay of ponds on the low ground south of the river at Wyfordby. In the broad tributary valley of Burton Brook, W. of Burton Lazars, where there is a chalybeate spring regarded by Prof. Judd as probably rising from the *Gryphaea arcuata* limestones (Bucklandi Zone),[2] débris of shale is seen in ponds near the spinney SW.

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[1] *See* Appendix I. p. 106. Two different versions of this boring are extant; and it is important to determine which is right. The two versions were published in *Rep. Brit. Ass.* for 1883 (pp. 153–4) as two distinct borings, and are described as such in "The Jurassic Rocks of Britain," vol. iii., *Mem. Geol. Surv.*, 1893, p. 171, and elsewhere in geological literature; though in the Survey memoir on "The Geology of the South-west Part of Lincolnshire," 1885, pp. 147–8, where both readings are reproduced, it is recognized that they refer to the same boring; and nothing is known locally of two separate borings. An independent account of this section has been communicated to us by Mr. Baldwin Latham, M.I.C.E., who received it from Mr. Johnstone, surveyor, of Melton Mowbray, who watched the boring. This account, in which depths only are given, substantiates in all material respects the version previously published on the authority of Messrs. Le Grand and Sutcliff, except in the lowest two or three feet, and in giving less detail of the uppermost 14 ft. There is every reason therefore to believe that Messrs. Legrand and Sutcliff's version gave the correct reading of the sinkers' record. The other version, in which the hypothetical geological divisions are stated without detail, besides differing somewhat from the above in the matter of depth, is widely divergent in interpretation, for while the former assigns only 38 ft. to drift deposits, the latter gives 149 ft. of drift, with corresponding lower levels for the bases of the Lias and the Rhætic. The evidence of the surrounding country renders it very improbable that the drift attains at this spot the depth allotted to it in the second version, and we therefore adopt the first-mentioned record as being the more trustworthy.

[2] "Geology of Rutland." *Mem. Geol. Surv.*, 1875, p. 61.

of Sapcoat's Lodge. The most southerly loop of the Eye, 800 yds. SE. of Wyfordby Rectory, exhibits a small section in the south bank as follows :—

	ft.	in.
Loamy soil with stones ... ... 1 ft. 6 in. to	2	0
Pockets of ferruginous, loamy and gravelly sand ... 0 to	1	6
Weathered shale with small calcareous nodules: loose specimens of *Pholadomya sp.* and *Pleuromya?* had probably fallen from this bed ... ... 2 ft. to	3	0
Thin-bedded blue shaly and micaceous limestone with *Gryphaea cymbium* Lam. and belemnites, up to	0	8
Blue shale	–	–

These beds, though of uncertain position, should certainly lie not lower than the Semicostatus Zone, and below the Jamesoni Zone. They may possibly represent the sandy bed at the top of the Semicostatus Zone further west (*see* above). Prof. Judd describes clay with much pyrites, producing selenite by decomposition, as seen in the Freeby railway-cutting, now obscured. He states that *Belemnites clavatus* Schloth. and *Plicatula spinosa* Sow. were abundant, and regards the horizon as a short distance above the Semicostatus ironstone.[1]

C. B. W.

Clays above the Semicostatus Beds (F).—The clays above the sandy top of the Semicostatus Zone are at present very poorly exposed, except in a few sections in the SE. corner of the map. In the NE. district, in the neighbourhood of Belvoir and Stathern, stream- and pond-sections everywhere show a clay subsoil, and the sandy horizon above described marks a slight change in the nature of the subsoil, of some agricultural consequence, between the more calcareous clays below and the less calcareous clays above it.

Blue shaly clay thrown out in making a wind-pump 150 yds. NE. of Brockhill Hall, 1½ miles S. of Hose, contained a band of calcareous and sandy rock and *Spiriferina*, *Gryphaea cymbium* and belemnites. Their position and the *Gryphaea* show that the beds belong to the upper part of the Lower Lias, but no further evidence was obtained. During the previous Survey Mr. Ussher noticed a layer of ferruginous nodules with *Liparoceras capricornus* and belemnites in the now-obscured railway-cutting 1¼ miles N. of Long Clawson Station,[2] and the following species were subsequently obtained by the Survey collector from this locality :—

Pentacrinus sp.	Unicardium cardioides (*Phill.*)
Rhynchonella (fragment)	Cerithium ?
Pecten liasianus *Nyst*	Acanthopleuroceras brevispina (*J. de C. Sow.*)
Plicatula spinosa *J. Sow.*	Belemnites longissimus ? *Mill.*
Pteria ?	„ sp.

This list rather suggests the Jamesoni Zone as the horizon of these beds.

C. B. W.

South of Long Clawson, grey-blue shaly clay with obscure small lamellibranchs is seen in the stream-gutter SW. of the Windmill, and between this place and Old Dalby there are a few other unimportant exposures of similar clay in ponds and small streams. The clay weathers to a rusty loam at the surface, and often contains small calcareous and ferruginous concretions. The cutting and tunnel on the Midland Railway ½ mile SE. of Old Dalby show that some of the beds of this division are rich in fossils. The shales, now very poorly exposed, in the sides of the cutting leading up to the tunnel yielded several species, which appear in the following list but unfortunately possess no zonal significance. The two spoil heaps around the shafts above the NW. end of the tunnel, from which many of the fossils recorded by Messrs. H. E. Quilter[3] and E. Wilson were obtained many years ago, still form a rich collecting ground. The species from this locality recorded by previous observers or contained in the collections of the Leicester Municipal Museum are included in the general list of Leicestershire Liassic fossils given by Mr. C. Fox-Strangways in a previous

[1] "Geology of Rutland." *Mem. Geol. Surv.*, 1875, p. 59.
[2] "Geology of the South-West part of Lincolnshire." *Mem. Geol. Surv.*, 1885, p. 32.
[3] "The Lower Lias of Leicestershire." *Geol. Mag*, dec. iii., vol. iii., 1886, p. 59.

memoir of the Survey.[1] The list given below represents a hasty collection made during the survey in 1906 and now preserved in the Palaeontological Department of the Survey.

Lower Lias Fossils, Old Dalby Tunnel.	*Lower spoil heap.*	*Upper spoil heap.*
Pentacrinus (columnals)		+
Montlivaltia *cf.* mucronata *Dunc.*	+	
„ *cf.* radiata *Dunc.*	+	
Serpula filaria? *Goldf.*	+	
„ tricristata? *Münst.*	+	
Microthyris darwini (*Deslongch.*)		+
Cincta numismalis (*Lam.*)	+	
Rhynchonella *cf.* fodinilis *Tate & Blake*		+
„ rimosa? (*von Buch*)		+
„ sp.	+	
Spiriferina *cf.* oxyptera *Buvign.*		+
Gryphaea cymbium *Lam.*	+	
„ sp.	+	
Hippopodium ponderosum *J. Sow.*	?+	+
Nuculana complanata (*Phill.*)	+	+
„ minor (*Simps.*)	+	
Pholadomya *cf.* ambigua *J. Sow.*	+	
„ sp.	+	
Pleuromya *cf.* elongata (*F. A. Roem.*)		+
Plicatula spinosa *J. Sow.*	+	+
Pteria (Oxytoma)?	+	
Unicardium cardioides (*Phill.*)	+	+
Cerithium?	+	
Chemnitzia *cf.* berthandi *Dumort.*	+	
Turbo sp.		+
Acanthopleuroceras brevispina (*J. de C. Sow.*)	+	+
Amaltheus? *cf.* trivialis (*Simps.*)		+
Cf. Platypleuroceras lataecosta (*J. de C. Sow.*) ...		+
Oxynoticeras oxynotum (*Quenst.*)	+	+
Belemnites acutus *Mill.*	+	+
„ *cf.* acutus *Mill.*	+	

With respect to the occurrence of the fossils, Mr. Quilter mentions, in the paper above referred to, that the Oxynotus Zone could formerly be examined remarkably well at the tunnel. He adds :—"The section is now [in 1886] unfortunately covered up, but the heaps of débris on the top of the tunnel show thinly-bedded laminated blue shales, with ferruginous and limestone nodules, and shelly bands of limestone. The shales when weathered are, in places, richly fossiliferous, and judging from their present position on the shale heaps, there would appear to be a regular disposition of the fossils in bands or levels in the section, species of fossils being confined to one place or heap in the débris."

This localisation of species is well brought out in the above short list, the corals, for example, being practically confined to the NW. or lower spoil-heap. The assemblage represents a mixture from the combined Oxynotus, Armatus and Jamesoni zones.

Clays similar to those of the tunnel form the hill slopes S. of Old Dalby up to the road E. of Wavendon Grauge. They are best exposed in a pit 350 yds. E. of Wavendon Grange, which shows 12 to 14 ft. of grey-blue marly clay weathering yellow, containing sandy 'boxstone' concretions and masses of bluish iron-stained limestone, up to 1 ft. in length, with the following fossils :—*Pentacrinus* columnals, *Gryphaea cymbium* Lam., *Ostrea irregularis?* Münst., *Ostrea sp.*, *Pecten* cf. *acuticosta* Lam., *Pecten sp.*, cf. *Unicardium cardioides* (Phill.), *Belemnites acutus?* Mill. and *Belemnites sp.*

[1] "The Geology of the Country near Leicester." *Mem. Geol. Surv.*, 1903. Appendix ii., pp. 95-115.

The spoil heaps near the SE. end of the tunnel are less rich in fossils than those near the opposite end, and we obtained nothing of consequence from them. The cuttings between the tunnel and Grimston Station are mainly in blue shaly clays of the Lower Lias, containing numerous belemnites and *Gryphaea* in places, but their slopes are now overgrown and obscure.

The possibility of a fault with a downthrow to the north was suspected, to account for the difference in the clays at the opposite ends of the tunnel, and for the presence of the Middle Lias Marlstone, as subsequently described (p. 49) in Old Dalby Wood, W. of the tunnel, but no evidence was obtained sufficient to justify the insertion of a fault on the map here. B. S.

For 4 or 5 miles south-eastward from the exposures near the Holwell Ironworks already referred to, the Lower Lias outcrop is almost entirely drift-covered, and it is not until we reach the valley of the Eye in the neighbourhood of Stapleford that its upper zones are again visible at the surface. In this quarter, a former exposure, now grassed over, "in Saxby Cutting" [apparently part of the disused loop of the railway immediately NE. of Saxby Station] has been described by Prof. Judd as exhibiting "light-blue laminated, highly pyritous shales with some thin bands of limestone, almost made up of *Pentacrinites* and small bivalve shells. They contain also small septaria, concentric balls of ironstone and pieces of jet . . . The most abundant fossils were *Ammonites bipunctatus* Röm., *Plicatula spinosa* Sow. *Inoceramus substriatus* Goldf., *Lima acuticosta* Goldf., *Spirifer walcotti* Sow., *Rhynchonella variabilis* Schloth., and *Pentacrinus punctiferus* Quenst."[1] Prof. Judd appears to regard the beds as lying a little below the Jamesoni Zone.

The drift-capped elevation of Hose Hill and Cuckoo Hill, 1½ miles SSW. of Stapleford has, along its W. foot, several ponds showing weathered shale with ferruginous nodules and numerous fossils, including *Gryphaea cymbium* Lam., *Ostrea sp.*, *Uptonia jamesoni* (J. de C. Sow.) (this ammonite preponderating over other but obscure forms), *Belemnites acutus?* Mill., *B. clavatus* Blainv. Beds of the Jamesoni Zone are also seen again in the banks of the stream at the SE. corner of Stapleford Park, as described by Prof. Judd,[2] and there consist of blue and somewhat calcareous clay containing small calcareous nodules and in one place a one-inch band of shelly limestone with oysters and belemnites. *Uptonia jamesoni* and belemnites are abundant in the clay. Prof. Judd records the following fossils from this or other exposures of the Jamesoni Beds in the park[3] :—

Ammonites latæcosta *Sow.* (abundant)
„ brevispina *Sow.* (rare)
„ capricornus *Schloth.* (rare)
„ jamesoni *Sow.*, var. confusus *Quenst.* (rare)
„ jamesoni *Sow.*, var. bronni *Röm.* (rare)
„ normanianus *d'Orb.* (rare)
„ jamesoni *Sow.*
„ polymorphus lineatus *Quenst.*
Belemnites clavatus *Schloth.*
„ elegans *Simps.*
Trochus sp.
Lima hermanni *Ziet.*
„ acuticosta *Schloth.*
Plicatula spinosa *Sow.*
„ laevigata ? *d'Orb.*
Gryphaea cymbium *Lam.*
Unicardium cardioides *Phill.* (U. ianthe *d'Orb.?*)
Cypricardia cucullata *Goldf.* sp.
Serpula sp.
Pentacrinus punctiferus *Quenst.*

Prof. Judd mentions that a deep well sunk in Stapleford Park reached blue clays with numerous *Gryphaea arcuata* and arietite ammonites, which he seems to have regarded as belonging to the Bucklandi Zone.[4] He does not further specify its position, but it may be the well 600 yds. SE. of the Hall, as we were informed that this was more than 100 ft. deep. Blue clay with abundant *Gryphaea cymbium* seems to have been dug about 300 yds. south of the Hall.

Where the above-mentioned disused loop of the railway near Saxby joins the present Peterborough line, on the NE. side of Stapleford Park, crumbled shale with ferruginous nodules can still be seen in the cuttings. In these beds *Liparoceras capricornus* (Schloth.) is the prevalent ammonite. This is the nearest exposure of undoubted Lower Lias to the neighbouring cutting in the line to

[1] "Geology of Rutland" *Mem. Geol. Surv.*, 1875, p. 60.
[2] *Ibid.*, p. 60.
[3] Loc. cit.
[4] "Geology of Rutland," p. 59.

Bourne, where Mr. H. B. Woodward, in 1892, when the section was fresh, found the Middle Lias Marlstone to be separated by an apparent fault near the W. end of the cutting from clays with small cement-stones, which he assigned provisionally to the upper beds of the Lower Lias (*see* p. 46).

Prof. Judd says[1] of "the railway-cuttings by the side of Stapleford Park" that "these beds abound with ammonites of the groups of the Armati and Capricorni, including *Ammonites lataecosta*, Sow., *A. brevispina*, Sow., *A. Jamesoni*, Sow., *A. Normanianus*, D'Orb., *A. armatus*, Sow., &c." But he does not particularize the beds above-described at the junction of the old and new cuttings as belonging to the Capricornus Zone, though he recognizes the Jamesoni Zone in Stapleford Park.[2]

South of the park, in the boundary-stream between Leicestershire and Rutland, blue shale with ferruginous bands, selenite, and belemnites, crops out below Laxton's Covert, near the road.

The scanty evidence afforded by the few exposures of Lower Lias in the neighbourhood as to the course of the zones, suggests that the strata of the Jamesoni Zone, after presumably following an easterly strike north of the Eye valley, turn southward and enter the N. end of Stapleford Park E. of the Saxby cutting; that they flatten so as to spread over the park and to occupy all the ground between its SE. corner and the W. flank of Hose Hill; and that they are followed on the NE. side of the park by the Capricornus Zone which is faulted against the Marlstone Rock-bed a little further east.

North of the Eye the little tributary streams seem to have cut through to the Lias in the lower parts of their courses. In one of these valleys dark blue shale was noted from a well at the targets of the rifle range NE. of Freeby. A bore-hole at Saxby close to the river penetrated 309 ft. of clays with limestone-beds (*see* Appendix I, p. 107). In view of the thickness of the higher zones in this district and the character of the strata penetrated, it is doubtful whether the bore-hole reached the *Gryphaea*-limestones of the Bucklandi Zone.

C. B. W.

[1] "Geology of Rutland," *Mem. Geol. Surv.*, 1875, p. 60.
[2] *Ibid.*, p. 61.

CHAPTER V.

MIDDLE LIAS[1].

GENERAL ACCOUNT.

The Middle Lias outcrop, deeply indented by the valley of the River Devon, enters the area at the north-eastern corner near Belvoir. From Belvoir Castle it runs south-westward in a bold, straight, and picturesquely wooded escarpment to Stathern, and is continued thence in the same direction through Harby Hills to near Long Clawson Station. Here it throws out a long narrow spur extending as far westward as the Midland Railway at Old Dalby. The outcrop then doubles back eastward to the neighbourhood of Scalford where it becomes covered with drift and remains masked and its escarpment obliterated by this deposit over the entire south-eastern part of the map, the only place where it is seen in this tract being in a railway-cutting near Saxby.

Lithologically, the Middle Lias is separable into two divisions:—(*a*) a lower portion, 100 to 120 ft. thick, consisting of bluish clays and sandy shales with an occasional nodular band of limestone, the whole akin in composition to the underlying Lower Lias; and (*b*) an upper portion, the Marlstone, very different in lithological character, consisting at the base of thinly bedded calcareous sandstones and sandy shales, passing up into sandy limestones, locally known as the 'sandrock,' overlain by ferruginous limestone and ironstone. The Marlstone division rarely exceeds 40 feet in thickness, but it is always strongly distinguished from the Middle Lias clays below and from the Upper Lias clays above, and by its superior hardness gives rise to the bold escarpment which marks its course.

Palæontologically, these two divisions are supposed generally to correspond (*a*) to the Zone of *Amaltheus margaritatus* Montf., and (*b*) to the Zone of *Paltopleuroceras spinatum*, Brug., but in this district the fossil evidence in support of this classification is very scanty. The characteristic ammonite (*Amalth. margaritatus*) of the lower zone, while abundant in the neighbourhood of Grantham,[2] 6 miles distant north-eastward, has not yet been found in the Middle Lias clays of the present map, though possibly this may be due merely to the absence of good exposure of the beds. But even in the upper division, in which numerous and extensive sections are afforded by the ironstone workings, the zonal ammonite (*Palt. spinatum*) is of extremely rare occurrence, and was not seen during the recent survey, though it has previously been recorded from Woolsthorpe and Scalford.[3] By far the commonest fossils of the Marlstone are the brachiopods, *Rhynchonella tetrahedra* and *Terebratula punctata*, which occur in countless numbers, clustered into globular masses; associated with them are many lamellibranchs and belemnites. Full fossil-lists have been given in previous

[1] By W. Gibson, C. B. Wedd, G. W. Lamplugh and B. Smith.
[2] "Geology of the SW. part of Lincolnshire." *Mem. Geol. Surv.*, 1885, pp. 36–7.
[3] *Ibid.* p. 128.

memoirs of the Survey[1] and need not be reprinted here, though a few species will be mentioned in the subsequent detailed description.

The value of the upper portion of the Marlstone series as an iron-ore, already referred to, has led to the wholesale removal of this bed throughout the district, wherever it occurs at or near the surface. The areas from which the ironstone had been thus wholly or in greater part removed at the time of the survey (1906) are indicated on the map by the stippling on the Marlstone outcrop. The position of the present workings is also stated in the following topographical notes, and the general consideration of the ironstone in its economic aspect is given in the final chapter of this memoir.

DETAILS.

The Middle Lias outcrop is separated into three main areas by the drift-filled troughs at Eastwell and Scalford, with a much smaller outlying patch, also isolated by the overlap of the drift, at the most westerly point of the outcrop, near Old Dalby. The northern tract, extending from Belvoir to Eaton is much dissected by the steep-sided valleys of the north-flowing Devon and its feeders; the middle tract, lying between Eastwell and Scalford, is deeply notched by the headwaters of a small stream flowing S. to the River Eye at Melton; and the third, or south-western tract, stretching from Holwell to Wartnaby is trenched by the ravine of Holwell Brook. It is in these several drainage channels that the principal exposures of the Middle Lias clays occur, though they are all poor and inadequate. The Marlstone series on the other hand is laid open in numerous natural exposures as well as in many extensive artificial sections.

In the northern area, the clays are seen at intervals in the banks of the streams between Knipton and Eaton. Probably the lowest beds visible in this drainage basin crop out in one of the tributaries of the Devon 200 yds. S. of Knipton Church. They consist of pale blue clays with calcareous nodules containing "*Aegoceras*" *sp.*, and *Nuculana sp.*, and occur from 60 to 70 ft. below the base of the Marlstone. At a slightly higher horizon, some unfossiliferous sandy shales and flags form the banks of the outflow channel of Knipton Reservoir. Near the watermill on the Devon at Eaton, blue clays with septarian nodules, lying about 50 ft. below the base of the Marlstone, crop out on the left banks of the river. The nodules yielded *Goniomya heteropleura*, *Chemnitzia?* *Belemnites* cf. *elongatus* and some indeterminable ammonites. A little further up the river, pale grey sandy shales are seen, which lie nearly at the summit of the lower clayey division of the Middle Lias. Elsewhere in the district occasional glimpses of pale blue, sparingly fossiliferous clays are afforded by small landslips along the wooded slopes of the escarpment between Stathern and the Terrace Hills.

On the slender evidence of these scanty exposures it is of course impossible to fix the lower limit of the Middle Lias with any certainty, and the line on the map is drawn on the assumption that these clays have a thickness of about 100 ft.

Between Knipton and Eaton, the Devon valley separates the Marlstone outcrop into two areas. The lower sandy part of the division remains constant in thickness and character in both; but the upper part varies considerably, being a soft decalcified richly ferruginous rock on the NW. side of the valley, and a hard massive ferruginous limestone on the SE. side. In both areas the gentle south-easterly inclination is persistent, and the outcrop is unbroken by faults.

The small outlier of Marlstone on which Belvoir Castle so conspicuously stands consists of a thin capping of ferruginous rock resting on calcareous sandstones and sandy shales. In the larger outlier forming Blackberry Hill, S. of Belvoir, the ferruginous rock occurs in a bed about 8 ft. thick, and has been quarried, along with the underlying sandrock, S of the Mausoleum. There are also some old quarries near the S. end of the hill.

[1] *Mem. supra cit.* and "Jurassic Rocks of Britain," vol. iii. *Mem. Geol. Surv.*, 1893, p. 188.

On the still larger outlier of High Leys, which stretches S., with an irregular indented boundary, nearly to Knipton, the upper layers of ferruginous marlstone have been partly removed by denudation, so that over the N. part of the outlier only the harder and less profitable lower beds are at the surface; but judging from the character of the soil, some of the more richly ferruginous rock still remains on the two lobes which extend towards the Devon valley. In a small quarry in a field near the cross roads W. of Windsor Hill the rock is a ferruginous sandy limestone containing numerous belemnites in clustered masses.

Over the broad marlstone outcrop between the Terrace Hills and Eaton the unvarying character of the sandrock is shown in numerous exposures, of which it is only necessary to mention the sections best exhibiting the sequence.

The following section of a quarry on the Terrace Hills, in a field opposite the end of the road running SE. through Barkestone Wood, may be taken as typical of the sandrock over this area :—

	ft.	in.
Soil	0	6
Subsoil, with numerous fragments of ironstone	2	6
Ferruginous limestone ... ... 0 to	1	0
Rhynchonella bed ... ... 0 to	0	8
Calcareous ferruginous sandstone with lenticles of ferruginous limestone	4	0
Blue-hearted ferruginous limestone	0	5
Ochreous-brown soft sandstone	3	0
Sandstone with clay pellets and rolled fossils	2	0
Sandy shales and flags in floor of quarry.		

In this section the impersistent bed with *Rhynchonella* is probably at the top of the sandrock series, and the material above this horizon seems to represent the remnants of the overlying ironstone subdivision. The sandy shales and flags in the floor of the quarry crop out in the escarpment and are there from 3 to 4 ft. thick. From the soft sandstone and the sandstone with pellets "*Aegoceras*" sp., *Modiola* cf. *hillana* J. Sow., *Pecten liasianus* Nyst, *Pecten sp.* and *Tancredia?* were obtained.

The carriage-drive along the crest of the escarpment in Stathern Wood follows the outcrop of the sandrock which is seen in section along the path by which visitors on foot generally enter the wood.

Around Eaton village exposures are numerous, and one of them affords the most fossiliferous outcrop of the sandrock that was met with in the district. The exposure referred to occurs in the small but deep stream-channel S. of Eaton Lodge, at the spot where it is crossed by the footpath from Eastwell to Eaton. The calcareous flags here laid bare yielded *Cardita cingulata?* Goldf., *Gresslya intermedia?* (Simps.), *Modiola sp.*, *Pteria* (*Oxytoma*) *inaequivalvis* (J. Sow.), *Pinna* cf. *spathulata* Tate, and *Protocardia truncata* (J. de C. Sow.).

The excellent sections revealed in the workings for the overlying ironstones in this district are described in a subsequent chapter (p. 93).

On the SE. side of the Devon the best section of the sandrock is in the road-cutting north of Branston. The overlying ferruginous limestone covering the broad tract E. of the valley gives rise to a plain sloping gently to SE. and S. up to the foot of the Upper Lias escarpment. Over this tract the Marlstone is hard and compact, and in consequence has been extensively quarried for building stone. Though the outcrop is continuous with the ironstone workings at Harston, a short distance beyond the E. margin of the map, the rock has not yet been raised as an iron-ore in this part. A large disused quarry in a field, 600 yds. N. of Cedar Hill and close to the main road, shows over 12 ft. of hard ferruginous limestone with numerous belemnites. The best section is in a quarry about ¼ mile E. of Branston Church near the point where the road leading E. from the village is joined by the road from Knipton; it shows, at the top, 10 ft. of platy ferruginous limestone, resting on 3 ft. of massive hard ferruginous rock. Another quarry on the right bank of the small stream E. of Croxton Lodge, near the gates at the S. entrance to the grounds of the Lodge, shows the ferruginous limestone as a hard compact rock made up of three beds, each a little under 3 ft. thick.

At Combs Plantation SE. of Stathern, the Middle Lias escarpment becomes obscured by drift, but it emerges again boldly near Eastwell and continues thence unbroken southward through Harby Hill till it again passes under drift E. of Long Clawson Station. The section exposed along the mineral tramway

down the escarpment W. of Eastwell repeats the sequence already recorded from the quarry above Barkestone Wood, but numerous small faults ('joggles') render the section obscure. The junction of the sandrock with the underlying clays is now no longer visible, but it was seen some 20 years ago by Mr. W. A. E. Ussher and described by him as follows in a previous memoir :—

"The tramway . . . near Eastwell shows the junction of the Rock bed with the Middle Lias clays. The Rock-bed rests upon soft, shaly, and micaceous sandy clays, with beds of friable sandstone at about 8 feet below the junction. The base of the Rock-bed is formed of 18 inches of conglomerate rock, with numerous phosphatic concretions ; above this there is no indication of the sandy clays which for 4 or 5 ft. below it are interstratified with friable sandy beds similar to the Rock bed in places, and which give evidence of an upward passage into the Marlstone." [1]

In the sandy shales at the top of the sandrock, fossils are plentiful and include:—*Gresslya intermedia* (Simps.), *Gresslya sp.*, *Hippopodium ?*, *Lucina ?*, *Pteria* (*Oxytoma*) *inaequivalvis* (J. Sow), *Protocardia truncata* (J. de C. Sow.).

South of the section described by Mr. Ussher there is no clear exposure of the Middle Lias clays in the escarpment, though their presence is indicated by the pale clay soil of the slopes of the Harby Hills. Yellow and blue clays belonging to this division were formerly seen under thin drift at the N. end of the tunnel close to Long Clawson Station,[2] but the cutting is now overgrown.

W. G.

Streams fed by springs rising in the Marlstone near Goadby Marwood and Wycomb have excavated a deep valley through the Marlstone into the underlying clays, which however are seldom exposed in section. Where the footpath from Bellemere Farm to Goady Marwood crosses this valley, an artificial water-channel on its W. side reveals a few feet of buff and pale grey sandy micaceous shale and shaly flags ; east of it a cutting along the footpath shows light brown and grey flaggy sandstone, with little nodules, a small *Pecten* and *Modiola*, alternating with light blue sandy micaceous shale at the junction of the clay-division with the Marlstone. In the side of the lane descending N. to the stream at Wycomb, 7 or 8 ft. of alternate pale grey shaly clay and yellowish-brown sandy and micaceous flags, from which Mr. Jukes-Browne records *Cardium truncatum* and *Avicula inaequivalvis*[3], may be seen not far below the base of the Marlstone.

A well 100 yds. NE. of the Manor House [4] at Wycomb is reported to have been sunk through about 50 ft. of clay ; another, at the same distance S. of the stream, and on the E. side of the lane, proved 20 ft. of shaly clay ; and a third, immediately N. of the Manor House, was in thick rock under thin clay.[5] But old pits 400 yds. NE of the same house show ferruginous Marlstone, although there is no evidence of its presence on the S. flank of the valley immediately W. of Wycomb. From the data of these wells, in conjunction with the featureless character of the ground and the inadequate space for the outcrop of the Marlstone before the oncoming of the Upper Lias, the fault shown on the map has been introduced on the assumption that the Marlstone has here been thrown down against the lower clays.

The uppermost beds of these clays were formerly seen "on the east side of the brook at Scalford, at the bottom of a steep bank near the spring. Here micaceous shales with thin layers of micaceous sandstone were found, the latter containing *Cardium truncatum*, *Avicula inaequivalvis*, and *Ammonites sp.* (*? spinatus*)."[6]

The large pit of the Lion Brick-works, a mile NNW. of Scalford affords the best exposure in the district. Pale clays with occasional thin sandy beds there rise almost to the surface under a mere remnant of the sandy Marlstone, though some distance within the outcrop of the latter. A well sunk in the NW. corner of this pit proved 75 ft. of clay with a 1½ ft. bed of limestone in its upper part. Another at the S. end of the brick-works, where the surface is apparently just below the base of the Marlstone, passed through 35 ft. of clay with a thin bed of

[1] Geology of the SW. part of Lincolnshire etc." *Mem. Geol. Surv.*, 1885, p. 38.
[2] *Ibid.*, p. 78. [3] *Ibid.*, p. 35.
[4] The Wycomb Manor House is not marked on the one-inch map ; it is at the top, and on the W. side, of the lane which descends N. from the main road at Wycomb. It must not be confused with the Manor House near Scalford which is shown on the map.
Information about these wells was supplied by Mr. J. T. Whitfield, well-sinker.
[6] Memoir *supra cit.*, p. 35.

limestone 15 ft. from the top.[1] The clay is present, but poorly exposed, in the neighbouring cutting of the mineral-railway; and sandy shale containing a 3 ft. bed of "marlstone with iron" 15 ft. from the top of it, is recorded from shafts of the Melton Mowbray Water-works, situated below the outcrop of the Marlstone sandrock on both sides of the railway. (*See* p. 45, and Appendix I, p. 107.)

The valley at Holwell also cuts into the Middle Lias clays. In its little branch 250 yds. NE. of the church, light-coloured sandy clay crops out beneath the sandrock. Thence northward along the deep cutting of the mineral-railway, to be described subsequently (p. 47), 3 or 4 ft. of clay is continuously, though obscurely, exposed below the sandrock as far as the bridge under the cross-roads, nearly a mile N. of Holwell. About 150 yds. further N. in the same cutting an E–W. fault intersects the section and throws up pale clays, probably belonging to this division, against the ferruginous sandrock.

At Chadwell, for ½ mile down the valley from the village, pale grey and blue clays cropping out from beneath the drift, are assigned as on the previous map (Sheet 70) to the Middle Lias. This is almost the only recognizable exposure of the clays along their southern outcrop under the sheet of boulder-clay.

The Marlstone of the tract between Eastwell and Scalford possesses the same general characters as in the tract already described to the northward. While its total thickness appears to be slightly diminished, the thickness of the ironstone is in places as great as, or even greater than, further north. Both the sandrock and the ferruginous rock vary in thickness, the latter also in character. Between Eastwell and Goadby Marwood a locally constant horizon is recognized, below which ironstone is not worked; but no general plane of division between the lower sandy beds and the ironstone has been found in the rest of the district; and it is probable that the depth of ferruginous replacement is somewhat variable in the upper part of the Marlstone previously more calcareous. (*See* Chap. X, p. 90.)

From the brow of the Harby Hill escarpment, the Marlstone slopes away gently north-eastward with an outcrop nearly 1½ miles in width, in which the surface of the ground nearly conforms to the dip of the strata. North-east of Long Clawson Station, however, the base of the Marlstone recedes from the great escarpment, which for some distance is composed entirely of the lower clays capped by drift. Here the outcrop of the Marlstone makes no feature, so that its lower margin, partly obscured by drift, and possibly faulted, becomes uncertain. Part of its boundary, S. of the loop of the mineral-railway, is probably determined by the fault described above as seen in the cutting north of Holwell.

From Eastwell southward, the upper part of the Marlstone has suffered progressively increasing denudation, until at a mile north of Scalford only a few feet of its lowest sandy beds remains, and it is only farther eastward that the series recovers its full thickness. The distribution of the ironstone-workings, as explained in a later chapter, is largely governed by this circumstance.

To the southward of the tract occupied by the Inferior Oolites the Marlstone is completely buried under drift, and the rock is seen only at one place, in a railway-cutting near Saxby. At the old windmill ½ mile SE. of Scalford, a water-bearing rock is reported to have been reached under 98 ft. of drift, the water rising 50 ft. in the tubes[2]; *i.e.*, approximately to the level of springs at the nearest outcrop of the Marlstone. On the most likely supposition that the rock was the Marlstone, the hypothetical boundary of the division has been drawn to include this spot.

The base of the division is exposed for nearly a mile across the strike in the cutting of the mineral-railway near the Lion Brick-works, N. of Scalford. Throughout this distance it remains within a very few feet of, or almost at the surface, as in the neighbouring pit of the brick-works (p. 43). The lowest beds are thin-bedded soft ochreous sandstones with layers of small nodules, probably phosphatic. They are overlain by thicker and more calcareous beds, with *Terebratula*, small pectens and belemnites. Old quarries S. of the railway and W. of the brick-works, show about 9 ft. of hard ferruginous and calcareous rock, dipping in a general south-easterly direction, with *Rhynchonella tetrahedra*,

[1] Information by Mr. J. T. Whitfield, well-sinker.

[2] Information supplied by Mr. J. T. Whitfield, whose account of the well differs from that recorded in the previous memoir (*supra cit.*, p. 154), in which the depth is given as 71 ft., with sand and gravel, instead of rock below. Mr. Whitfield is, however, confident of this statement, and he has a wide knowledge of all wells in the neighbourhood.

Terebratula and belemnites. This represents the upper beds seen in the railway and others slightly higher. A well at the house 400 yds. ESE. of Wolds Farm proved 18 ft. of rock overlying 12 ft. or more of clay.[1]

The lower boundary of the Marlstone is difficult to trace in some of the valleys N. of Scalford; but the shafts and trenches of the Melton Mowbray Water-works have afforded much information. The main pipe runs N. along the lower road on the E. side of Scalford Churchyard, and thence along the footpath to Goadby Marwood for some distance beyond the mineral-railway. The latter part of its course is chiefly within the Marlstone, to which must be assigned the uppermost 7 ft. of the beds passed through 350 yds. NE. of the railway. In a shaft-section at this locality the next 15 ft. of lower beds is described as "sandy shale," above 3 ft. of "Marlstone rock with iron," underlain by more "sandy shale." It seems likely that the "Marlstone rock" is the same band as the 18 in. bed of limestone that was reached beneath 15 ft. of clay in the wells at the Lion Brick-works (*see* above, p. 43). A branch-pipe, leaving the main at 150 yds. SW. of the railway, runs NW. up a side-valley, in which it passes below the base of the Marlstone into sandy shales and blue clays with occasional thin calcareous and sandy bands. In these it continues nearly as far as the Lion Brick-works.[2]

Ferruginous and calcareous sandstone crops out in the lane close to the Wycomb Manor House; and similar rock is seen in the road-side at Scalford SW. of the church.

In making the old covered reservoir of the Melton Water-works, ¼ mile SW. of Scalford Station, in the drift-covered area, brown sandstone, in all probability the base of the Marlstone, was seen to crop out under 10 or 12 ft. of stony clay.[3]

At Holwell the Marlstone escarpment on the E. side of the valley consists of thin-bedded yellowish-brown sandstone imperfectly seen in the tramway up to the level ground at the top, and contains belemnites and *Rhynchonella tetrahadra*. The same beds are exposed above the underlying clays in the railway-cutting further north.

The upper ferruginous beds of the Marlstone are well exposed on the S. side of Eastwell in the tramway-cuttings and workings of the Staveley Company. For the distance of a mile or more from its basset edge the rock is extensively decalcified and soft. The fossils have for the most part been dissolved out, but the rock shows numerous casts of *Rhynchonella* and *Terebratula*. In this neighbourhood the following general sequence is recognized in the ironstone beds:—

Good stone	3 ft. – 4 ft.
Sandy shelly bed, passing eastward irregularly into lime-rock	1 ft – 1 ft. 6 in.
Good stone	3 ft. – 5 ft.
Thin 'shale'	—— – —— ½ in.
Sandrock	——

The thin 'shale' of the above section consists of one or two irregular ¼ in. layers of a dark brown highly ferruginous substance which seems to mark the downward limit of ferruginous percolation.

As it approaches the Upper Lias eastward, the ironstone begins to retain more of its original calcareous character. The change, though taking place gradually and somewhat irregularly, first becomes strongly marked in the tramway-section about a ¼ mile from the Upper Lias outcrop, and remnants of Upper Lias clay here make their appearance in enlarged joints in the limestone. Where it passes under these clays, the whole thickness of the ironstone becomes, as usual, strongly calcareous and harder, this phase of the ironstone being evidently dependent upon the more recent removal of its impervious cover, while its decalcified and highly ferruginous phase at a greater distance from the clay outcrop indicates its longer exposure to weathering (*see* p. 91).

At the E. end of the workings near White Lodge, where the stone has a cover of Upper Lias clay reaching 13 ft. in thickness, it is worked to a depth of about 10 ft., and consists of hard brown ferruginous limestone, largely decalcified, but containing cores of greenish-blue limestone in its lower part. The usual

[1] Information by Mr. J. T. Whitfield.

[2] The sections of the shafts sunk along the lines of the water-pipes were communicated by Mr. Baldwin Latham. Two of these are given in Appendix I, p. 107.

[3] Information by Mr. W. Fowler.

fossils—*Rhynchonella*, *Terebratula*, pectens and belemnites—are abundant. The uppermost 2 or 3 ins. of the rock is crystalline and pale in colour. North of the farmhouse 250 yds. E. of White Lodge, the surface of the ironstone is rendered curiously serrated by the effect of several small step-faults which have a general NW. direction, with a maximum NE. downthrow of 5 ft., but which are hardly traceable upward in the overlying clay. A 5 ft. fault of similar direction and throw is shown in the Staveley Company's plans of these workings on the N. side of the mineral-railway.

On the E. bank of the valley between Goadby Marwood and Bellemere Farm, thin-bedded ferruginous and calcareous sandstone with *Rhynchonella tetrahedra* is seen in a small pit 520 yds. W. of Park Farm. Several old quarries, probably opened for building material, on the NE. side of Wycomb, show 6 or 7 ft. of ferruginous limestone with the usual fossils.

At Scalford, wells at the Plough and Black Horse Inns, both situated on the uppermost beds of the Marlstone, were sunk respectively in 16 ft. and 14 ft. of rock.[1]

The upper beds of the Marlstone, overlain by traces of Upper Lias clay, were seen by Mr. H. B. Woodward, in 1892, in the cutting of the Midland Railway on the line to Bourne, nearly a mile E. of Saxby Station,[2] and there is still a small exposure of ferruginous limestone dipping to NW. Mr. Woodward found evidence that this Marlstone was separated by a fault from the Lower Lias clays seen a little further W. in the cutting (*see* p. 39). Though the trend of the fault is wholly conjectural, it is clear that the Marlstone lies entirely within the drift-covered hill traversed by the cutting. Consequently the line of fault has been continued along the foot of this hill in a general NNE. direction, on the assumption that the rising ground which this line intersects, about ½ mile farther N., is merely a drift feature, like other hills in the neighbourhood.

South-west of Stonesby the hypothetical boundaries of the Marlstone under the boulder-clay have been drawn a little further S. than their position on the old map, for a reason which will be stated below (p. 53).

The third, or south-western, important tract of exposed Marlstone, lying W. of the drift-filled depression followed by the G.N. and L. & NW. Joint Railway, extends W. from the neighbourhood of Holwell to a little beyond Wartnaby. At its E. side the Stanton Company's workings E. of Holwell afford a fine section of the ironstone, of which a maximum thickness of about 14 feet was seen (in 1906) at the S. end of the workings, where it is overlain by the Upper Lias. The rock consists for the most part of brown limestone, more or less decalcified and ferruginous, but with cores of the unaltered greenish-blue calcareous and oolitic rock in the lower part. The whole contains in abundance the usual Marlstone fauna :—*Rhynchonella tetrahedra* in clusters, *Terebratula*, pectens and other lamellibranchs, and belemnites. At the top there is frequently a few inches of crystalline limestone resting on about a foot of soft ochreous and loamy ironstone. As in the White Lodge section, previously described, the surface of the ironstone shows a series of close-set step-faults of very small displacement, striking NW., and having hardly any traceable effect on the Upper Lias clay.

In the old workings at Brown's Hill, immediately to the S., a section of similar ironstone is exposed under thin Upper Lias ; one foot or 18 inches at the top is here particularly rich in belemnites ; and parts of the rock show current-bedding and are often crowded with crinoid ossicles. The dip, south-easterly throughout the greater part of this neighbourhood, changes locally to a northerly inclination at the S. end of this section. North-east of Old Hills Wood an old quarry shows 9 ft. of hard ferruginous limestone.

C. B. W.

For nearly 2 miles SW. from Long Clawson Station the Marlstone is continuously masked by the broad lobe of drift previously mentioned, which juts out across the Middle Lias clays to form the capping of Clawson Hill. In the neighbourhood of Holwell Mouth—a steep coombe cut back by springs issuing from the base of the Marlstone—the escarpment emerges clearly again and continues westward for 2½ miles as a bold unbroken feature to Green Hill where it is once more partly masked by drift. West of Green Hill, the Marlstone is not again seen except in the obscure exposure in Old Dalby Wood about a mile distant, described below (p. 49), and its continuity beneath the drift, along the

[1] Information by Mr. J. T. Whitfield.

[2] "The Jurassic Rocks of Britain," vol. iii. *Mem. Geol. Surv.*, 1893, p. 170.

course shown by the dotted lines on the map, is questionable, as there is much probability that its narrow spur between the Green Hill highroad and the Midland railway may be cut through by yet another drift-filled hollow.

The Middle Lias clays which form the slope of the escarpment between Holwell Mouth and Green Hill are nowhere clearly exposed. Here and there the ditches and road cuttings reveal a little greyish blue sandy clay, weathering yellow, usually much mixed with the slipped and rain-washed detritus of the Marlstone, but there is no evidence available on which to base the separation of these clays from the clays at the top of the Lower Lias. The line of division shown on the map is therefore, so far as this district is concerned, inserted solely on the supposition that the first 100 ft. of the clayey series below the base of the Marlstone belongs to the Middle Lias. Loamy sand has been dug from a small pit 10 ft. in depth on the lower slope of the escarpment 300 yds. W. of Stonepit Spinney, but it is not clear whether this is derived from a sandy bed in the clays or from the downwash and slipping of the Marlstone.

The best exposure of the basement beds of the Marlstone is in the deep cutting on the mineral railway about ½ mile N. of Holwell, previously referred to (p. 44). This section has a length of about 700 yds. and attains a depth of 30 ft. At the base, in the S. part, sandy blue clay or shale is poorly exposed to a depth of 3 or 4 ft. and is overlain by 12 ft. of flaggy calcareous sandstone or 'sandrock' with shaly partings. The upper part of the section shows 10 to 15 ft. of massive brown ferruginous rock with a concretionary structure, which is separated from the flaggy beds below by a thin irregular band containing small yellowish nodules, apparently rolled and water-worn, together with bits of crinoids, belemnites, oysters and other shells, mostly showing signs of wear. This band evidently marks a local pause in the sedimentation, accompanied by current-action. The flaggy beds possess their usual fossils in abundance, while the massive overlying rock, which at this locality is not rich enough in iron to constitute a good ore, contains many clustered masses of brachiopods. The N. end of the cutting, though partly sloped and grass-covered, reveals clear evidence of the previously mentioned E—W. fault by which the Marlstone is truncated in this quarter (p. 44).

The 'sandrock' was formerly much used locally as a building-stone, but is now rarely quarried for this purpose. Indications of the old quarries are numerous in many parts of the outcrop, especially around Holwell and Ab Kettleby, and at Stonepit Spinney ½ mile NW. of Wartnaby, but the sections are either obliterated or nearly so. There is a small open quarry, however, by the side of the mineral tramway S. of Stonepit Spinney, which shows 10 ft. of massive calcareous sandstone, much jointed and full of clustered brachiopods and other fossils. The lowest beds are also exposed, to a depth of 10 ft., in a small pit on the crest of the escarpment just outside the W. angle of the fence of Stonepit Spinney; they consist of soft loamy sandstone, very thinly bedded, almost shaly, containing the casts of many small lamellibranchs. The following species were collected here[1].—*Astarte striato-sulcata?* F. A. Roem., *Protocardia* cf. *truncata* (J. de C. Sow.), *Pseudomonotis* cf. *substriata* (Ziet.), and *Lima sp.*, *Pecten sp.*, *Cardita? Nuculana?* and *Placunopsis?*

The iron-ore forming the upper part of the Marlstone has been worked with hardly a break from Holwell westward to ½ mile beyond Wartnaby, where the rock is overlapped by boulder-clay. As a general account of this industry is given in a later chapter (X. p. 90), it will only be necessary here to refer to those sections which are more particularly of geological interest.

The workings of the Bennerley Co. in a field 500 yds. SE. of Holwell Mouth revealed, in 1906, a small irregular patch of Upper Lias clay, 2 to 4 ft. thick, much disturbed and weathered, resting on Marlstone which was workable as an iron-ore to a depth of 6 or 7 ft. A small fault, with a N. upthrow of about 8 ft. runs through these workings and cuts out the Upper Lias; and we were informed that the clay was also cut out on the SW. side by another similar fault with an upthrow which brings the 'sandrock' against the Upper Lias, the two faults uniting so that there is only a small wedge of the Upper Lias clay let in between them. The first-mentioned fault appears to be prolonged towards W. 15° S. for at least as far as Ab Kettleby Lodge, 900 yds. distant, its presence explaining the long strip of barren sandrock which reaches the surface between the Bennerley

[1] Determined and preserved in the Palæont. Deptmt. of the Survey.

ironstone pits and Ab Kettleby Lodge. Practically all the ironstone has been removed S. of this fault to as far W. as the highroad between Ab Kettleby and Broughton Hill, and the area N. of the fault will likewise be soon exhausted.

The workings of the Stanton Co. 500 yds. W. of Ab Kettleby Lodge have also revealed a fault, striking S. 30° W., with an upthrow of not less than 8 ft. on the NW. side, which has a similar effect in bringing in a strip of unproductive sandrock between two tracts in which ironstone has been worked. Its direction differs rather widely from that of the fault above described, but the two may be parts of a single swerving fracture. A section in the workings S. of this fault shows 10 ft. of ironstone resting on ochreous sandrock, with a capping of 3 ft. of rock-rubble which includes an occasional erratic boulder and pockets of drift pebbles. Similar sections occur at the edge of old ironstone workings all along the S. side of the cross-road 200 yds. farther N., and again in the fields N. of Wartnaby. The most recent workings (1908), in a field 350 yds. N. of Wartnaby Church, have revealed a patch of weathered yellowish clay 2 to 3 ft thick, apparently a remnant of the Upper Lias, occupying a broad sag or hollow in the ironstone which is here reduced in thickness so that the sandrock in one place is not more than 3 or 4 ft. from the surface.

The most westerly of the workings, and geologically the most interesting is close to Stonepit Houses,[1] 1,000 yds. WNW. of Wartnaby Church. At this place the ironstone has been followed up under a rapidly thickening cover of boulder-clay which is 15 ft. deep in one part of the pit. This clay has partly protected the marlstone from weathering, so that instead of being a friable earthy stone, as it usually is in the shallower workings, the rock is a dense calcareous ironstone, rusty-brown along all the joints and for a little way in from them, but dark blue or greenish in the middle of the blocks. This ironstone is from 8 to 14 ft. thick, with the usual sandrock below. It has an extremely irregular hummocky surface beneath the drift, and in several places the tops of the hummocks show glacial striations, as described in a later chapter. (*See* Plates I. and III., and Fig. 6, p. 70.) When the section was examined in 1906, a deep 'gull' or crevice 4 ft. in width was visible in the top of the rock at the entrance to the workings, into which a mass of blue shaly Upper Lias clay had been let down and preserved, forming a sharp little syncline. Among other Upper Lias fossils, the clay contained in abundance, the characteristic ammonites—*Dactylioceras annulatum* (J. Sow.), and *Harpoceras serpentinum* (Rein.), along with *Belemnites unisulcatus?* Blainv.

This disturbance may be due to the proximity of a small fault, or of a roll in the bedding having the effect of a fault, which appears to strike NW. from Wartnaby to Stonepit Houses. The dislocated rock has, however, evidently been further affected by glacial agency, as the southern part of the workings, 300 yds. S. of Stonepit Houses, shows the masses of shattered ironstone to be sometimes almost enveloped in boulder-clay, and we were informed that in trials beyond the southern limits of the workings the ironstone was found only in detached blocks.

During the steady quarrying of the ironstone, fresh points of interest are constantly being revealed in this section. Thus, when re-visited in the autumn of the present year (1908), it was found that the main working face of the quarry had intersected a still more spacious 'gull' which extended down to the floor of the excavation and quite cut out the ironstone for the space of 6 or 8 ft. at the bottom, expanding upward to twice or thrice this breadth, as shown in Fig. 6, p. 70. The bottom of the gull contained 4 or 5 ft. of much disturbed Upper Lias, with the same fossils as were found in the smaller gull above mentioned, while the remainder was filled with tough compact boulder-clay continuous with the main mass overlying the ironstone. Other noteworthy features of the section are indicated in the letterpress descriptive of Fig. 6.

A third fossiliferous gull of Upper Lias, smaller than either of the above, was noticed in the eastern face of the workings, now suspended. The presence of this entrapped material denotes that the crevices were formed before the covering of Upper Lias had disappeared from the plateau, while the state of the larger crevice shows that the ice of the Glacial Period has played its part in removing all except these few well-protected relics of the formation.

G. W. L.

[1] This name does not appear on the one-inch map. On the six-inch map it is applied to the cottages situated by the roadside 150 yds. SW. of Stonepit Spinney.

The meagre evidence respecting the western termination of the Middle Lias S. of Old Dalby is as follows. The lower clayey division forms the steep slopes S. of the village, which are strikingly dissected and imbricated by streams heading at the base of the boulder-clay. The clays contain ferruginous and sandy 'boxstone' concretions, but have yielded no fossils here; their base is, as usual, obscure, but a lithological change is suggested by the presence of at least three important springs along this line.

The Marlstone occurs several hundred yards farther W. than was indicated on the old Survey map, for it crops out from beneath the drift-plateau in a steep west-facing scarp along the upper margin of Old Dalby Wood. It is scantily exposed here in a few low crags, partly due to landslips, 60 to 70 yds. S. of the NE. edge of the Wood. Near the top, the rock is crystalline, ferruginous, and full of flattened oval pebbly-looking concretions, with a few feet of more sandy flaggy rock below, which yielded *Astarte sp.*, *Cardita ?*, *Lima sp.*, *Pteria* (*Oxytoma*) *inaequivalvis* (J. Sow.), *Pecten sp.*, *Placunopsis ?*, *Protocardia* cf. *truncata* (J. de C. Sow.), *Pseudomonotis* cf. *substriata* (Ziet.) and *Pseudomonotis sp.* The beds evidently belong to the lower part of the Marlstone, the pebbly-looking band being probably equivalent to the similar band noticed in the railway cutting at Holwell and elsewhere (p. 47). If the higher ironstones are present in this quarter, which is very doubtful, they are completely hidden by the boulder-clay which extends close up to the edge of the escarpment.

B. S.

CHAPTER VI.

UPPER LIAS.[1]

GENERAL ACCOUNT.

The Marlstone passes eastward under the Upper Lias which consists almost entirely of blue more or less shaly clays, of which the total thickness in south-west Lincolnshire has been estimated at about 120 ft.[2] The thickness of the Upper Lias within the area under description is fairly represented by this estimate, but shows a marked northerly decrease from the 200 ft. assigned by Prof. Judd[3] to the formation in Rutland.

The Upper Lias of the present area forms, with its several small outliers, a spur projecting from the main outcrop, dependent upon, but less prolonged than, that of the Middle Lias. It is much obscured by drift, which tends to cling to these clays, so that where the boulder-clay comes on above the Marlstone, it very frequently conceals patches of the Upper Lias. The outcrop of the division, owing to the protection afforded to it at present or in the past by the overlying Northampton Sand, is usually marked by a well-defined rise, often graduating into a strong bank, above the flat or gently sloping surface of the Marlstone.

The formation has been subdivided into the following groups[4] :—

(*d.*) *Leda ovum* Beds :—Blue clays, with layers of septarian nodules, containing the lamellibranchs *Nuculana ovum*, especially characteristic of these beds, and *Gresslya donaciformis* with the ammonites *Hildoceras bifrons*, *Dactylioceras commune*, *Harpoceras serpentinum*, and *Phylloceras heterophyllum*.

(*c.*) Communis Beds :—About 50 ft. of dark blue clays with jet and nodules of iron pyrites, but few fossils. Laminated blue clays with *Dactylioceras commune*, *D. annulatum* and other ammonites.

(*b.*) Serpentinus Beds :—Shales with limestone nodules of coarser texture than those of the lower beds : falcate ammonites abundant and often of large size, including *Harpoceras serpentinum*, *H. falciferum*, &c.

(*a.*) Dumbleton Beds (= Annulatus Beds) :—Finely laminated blue shales with bands of flat nodules of argillaceous limestone : the surfaces of the beds are often completely covered with scales and fragments of fish, together with remains of insects and small crustaceans.

Owing to the lack of suitable exposures, however, only a part of the above sequence can be recognized in the area under description. The lowest beds up to 12 or 14 ft. above the base are frequently laid open where the workings for the Middle Lias ironstone are continued within the margin of the Upper Lias outcrop. The uppermost 17 ft. has been excavated in the Stonesby brickyard, which is the only section now exhibiting the highest beds. But these are the only portions of the formation that are at present fairly exposed within the district.

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[1] By C. B. Wedd.

[2] "Geology of SW. Lincolnshire, &c." *Mem. Geol. Surv.*, 1885, p. 42.

[3] "Geology of Rutland &c." *Mem. Geol. Surv.*, 1875, p. 79.

[4] *See* J. W. Judd, "Geology of Rutland, &c." *supra cit.*, p. 79 ; and A. J. Jukes-Browne, "Geology of SW. Lincolnshire, &c." *supra cit.*, p. 42.

All the Upper Lias strata seen in the ironstone-quarries have been assigned to the Dumbleton Beds.[1] The "fish and insect" fauna is perhaps not so well represented as in neighbouring districts, but is distinctly noticeable in a layer of flat nodules of cream-coloured limestone resting directly upon, and often welded on to, the surface of the Marlstone. Prof. Judd describes the subdivision as containing, in less abundance and of smaller size, the same forms of ammonites as characterize the Serpentinus Beds;[2] but the relative abundance of *Dactylioceras annulatum* (J. Sow.) accompanied by forms closely resembling, if not identical with, *Harpoceras exaratum* Blake, is a sufficiently clear indication that the lowest 12 or 14 ft. of the Upper Lias exposed in the ironstone quarries belongs to a horizon below the Serpentinus Beds, therefore to the Dumbleton Beds. The absence or comparative scarcity of the characteristic ammonite of the higher zone and the presence of the lamellibranch cf. *Astarte depressa* Goldf. support this conclusion, with which the few other species identified are in harmony (*see* 'Details' below).

With respect to the highest beds of the formation, which are seen directly to underlie the Northampton Sand in the Stonesby brick-pit, there is little or no palæontological evidence as to their zonal position. The apparent absence of *Nuculana ovum*, usually so abundant in the highest subdivision of the Upper Lias, leaves a doubt whether this subdivision is really present in the district or whether in its absence the strata in question may belong to the unfossiliferous upper part of the Communis Beds. Prof. Judd regards the base of the Inferior Oolite in Rutland as often lying upon an eroded surface of the Upper Lias;[3] but we have no decisive evidence of this condition in the present case.

DETAILS.

The most westerly point at which the Upper Lias has been noticed is in the ironstone workings ½ mile WNW. of Wartnaby, where small patches have been preserved in the deep 'gulls' or open joints of the Marlstone as previously described (p. 48). Isolated and weathered patches of the formation were also seen at intervals in the workings between this place and Holwell (*see* pp. 45, 47).

Immediately E. of Holwell the western margin of a larger outlier emerges from beneath a protective cover of drift, and its base has been well exposed in some of the ironstone workings. In the old workings at Brown's Hill 2 or 3 ft. of pale blue laminated clay is seen to contain abundant lamellibranchs closely resembling *Astarte depressa* Goldf. together with *Inoceramus dubius?* J. de C. Sow. and small ill-preserved falcate ammonites apparently of the genus *Harpoceras*. A better section at the Stanton Company's quarry immediately to the north shows a cover of 14 ft. of Upper Lias, consisting of light blue shaly clay, pale in the lower part, probably from abstraction of iron. The lowest 6 or 8 inches is a soft buff or ochreous clay with calcareous layers and flat cream-coloured nodules containing abundant fish-fragments. Characteristic Upper Lias fossils occur chiefly about 5 or 6 ft. above the bottom. *Pseudomonotis sp.* is present in great numbers, with the *Astarte*-like lamellibranch found at Brown's Hill. *Dactylioceras annulatum* (J. Sow.) and *Harpoceras sp.*, both rather abundant, attain a fairly large size, while *Belemnites* cf. *elongatus* Mill. was also obtained.

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[1] "Geology of SW. Lincolnshire, &c." pp. 42–3.
[2] "Geology of Rutland, &c." p. 79.
[3] *Ibid.*, p. 90.

In the outlier on the NW. side of Scalford there was formerly a good section in a brickyard, described in the previous memoir[1] as follows :—

	ft.
"Shales with lenticular nodules	16
Shales with continuous floors of limestone	8
Hard Marlstone rock"	—

"The clay is crowded with flattened shells, and contains layers and nodules of the 'fish-and-insect limestones,' containing ammonites and other shells and the usual fragments of fish, insects and crustaceans. A fine fish ('like a sole') is said to have been found here."

Immediately beneath the overlying drift the edges of the shales were noticed to be bent up in one place, as though by the movement of ice from a northerly direction.

Recent evidence from wells has proved the extension of this outlier of Upper Lias into the village of Scalford, where it emerges from under the boulder-clay with a well-marked rise above the Marlstone. In a well 280 yds. NW. of Scalford Church, 3 ft. of blue shale with *Dactylioceras sp.* was passed through, beneath 58 ft. of boulder-clay: in another well, 250 yds. NNW. of the church, beneath 52 ft. of stony clay, 6 ft. of "blue bind" was found, resting upon ironstone.

At the main outcrop, E. of Scalford, a somewhat larger and more continuous area of Upper Lias has been represented than was shown upon the old map, and it is extended unbrokenly into the crescentic continuation of this outcrop which swings northward past Wycomb, Goadby Marwood and White Lodge, nearly to Eastwell. Throughout this distance the Upper Lias comes on above the Marlstone either in a gentle rise or in a strong bank. The faults seen in the mineral-railway E. of Scalford, as described and figured in the former memoir,[2] do not bound this outcrop. The presence of 55 ft. of blue shaly clay in a well by the road-side ¼ mile E. of Goadby Marwood Church, suggests the possibility of a fault there; but from that point to the Staveley Company's ironstone workings, E. of White Lodge, it is clear that the Upper and Middle Lias have on the whole a normal junction. It is seen in the ironstone quarry, 230 yds. E. of White Lodge, that several little north-westerly step-faults with north-easterly downthrow traverse the junction of these two divisions, and their NW. continuation has been proved a little farther on in the Marlstone; but again, the parallel outcrop of the Upper Lias in the direction of Eastwell seems still to be unfaulted, and numerous trial-borings within that outcrop gave no indication of faulting.

A section in the now overgrown mineral-railway cutting E. of Scalford is described by Mr. Jukes-Browne[3]:—"In a landslip about 75 yards north of the bridge in this cutting the following exposure was observed by Mr. Dalton and myself in 1882 :—

	ft.
"Soil	1
"Stiff blue clay	3
"Brown ferruginous shaly clay with ironstone nodules ...	3
"Dark blue shaly clay with fragments of *Am. serpentinus* and *Belemnites*	6
"Talus below	4"

A trench 300 yds. W. of Chadwell Church revealed 7 ft. of blue shaly clay, containing ill-preserved ammonites, apparently *Dactylioceras*, and possibly representing a slightly higher horizon than the exposures of the Upper Lias basement-beds in the ironstone workings. Fragments of falcate ammonites were found in the clay of ponds E. of Goadby Marwood.

The basal or Dumbleton Beds are again very well exposed in the ironstone-workings already referred to E. and NE. of White Lodge. The section in the quarry 250 yds. E. of the Lodge showed (in 1906) 11 ft. of blue shaly clay, light-coloured at the bottom, with darker seams above, resting upon the ferruginous limestone of the Middle Lias, traversed by small step-faults seldom recognizable

[1] "Geology of SW. Lincolnshire, &c." p. 43.
[2] *Ibid.*, p. 43.
[3] *Ibid.*, p. 44.

in the clay. The quarry 400 yds. NE. of the Lodge gave the following section :—

	ft.	in
Clay soil	3	0
Blue shaly clay with calcareous nodules containing ammonites : *Belemnites* cf. *ilminstrensis* Phill., *Harpoceras* cf. *exaratum* Blake	13	0
Layer of flat cream-coloured calcareous nodules, often welded on to the surface of the limestone below :—*Inoceramus sp.* ; abundant fish-remains ... ... about		1
White crystalline limestone		2–3
Massive ferruginous limestone (Marlstone)		—

The lithological change from the limestone to Upper Lias clay is abrupt in all these sections, but there is some doubt whether the two or three inches of light-coloured crystalline limestone at the top of the ferruginous limestone belongs to the Middle Lias or should be regarded as the basal layer of the Upper Lias.

East of the above section no exposures were found in the northern outcrop of the Upper Lias. From Scalford eastward the representation of its southern outcrop beneath the drift is almost wholly conjectural. South-west of Stonesby, however, the continuity of blue clay for a considerable distance below the outcrop of the Inferior Oolite in the valleys free from drift has led to the adoption of a rather more southerly base line for the Upper Lias than that represented on the old map.

The solitary section in the highest beds of the Upper Lias at the Stonesby brick-pit, mentioned in the first part of this chapter (p. 51), is now obscured in the lower portion, and the following details of it are based partly upon observation and partly upon information supplied by the foreman :—

	ft.
Brown sandy ironstone (Northampton Sand)	14
Unfossiliferous blue shaly clay, at the bottom a layer of pyritous and calcareous nodules producing much selenite on decomposition	11
Clay	6
Layer of large septaria, said to contain fossils	—

In the corner of the excavation the Northampton Sand is faulted down on the north against the clay.

In the cutting of the Bourne and Saxby Railway, E. of Saxby Station, Mr. H. B. Woodward noted traces of Upper Lias above the Marlstone there exposed (*see* p. 46).

C. B. W.

CHAPTER VII.

INFERIOR OOLITE.[1]

GENERAL ACCOUNT.

The variable Inferior Oolite sequence of the Midlands, incompletely represented in this district, in so far as the lower beds alone of the Lincolnshire Limestone are present, is tabulated below in descending order. Its outcrop here forms part of a faulted outlying tract severed from the main outcrop. It occupies an area of less than 5 sq. miles, and constitutes the higher ground between Waltham-on-the-Wolds, Stonesby and Croxton Park.

			Ft.
Lincolnshire Limestone		More or less oolitic compact creamy white or bluish-grey limestone with beds of shelly ragstone and calcitic coralline limestone; in the lower part occasional thin bands of clay; thin flags of sandy limestone at the base; the whole is characterized by numerous marine fossils, including *Latimaeandra davidsoni* Edw. and Haime, *Pygaster semisulcatus* (Phill.), *Terebratula maxillata* J. de C. Sow., *Rhynchonella cynocephala* Rich., *Lima pontonis* Lyc., *Trigonia striata* J. Sow., *Nerinella cingenda* (Phill.). Out of a total thickness of rather more than 100 ft. in south-west Lincolnshire, only the lower part is represented, and though a rather greater thickness is probably present, is not known to exceed	26
Northampton Beds.	Lower Estuarine Series.	Variable sands and clays with vertical rootlets and other plant-remains; also rarely estuarine shells; up to about	16
	Northampton Sand.	Greenish-blue arenaceous ironstone and ferruginous sandstone, the whole weathering at the surface to brown more or less highly ferruginous sandstone or sand; poorly fossiliferous as a rule, though parts of the ironstone are locally crowded with *Terebratula trilineata* Tate and Blake, *Modiola* cf. *cuneata* J. Sow., and other marine shells: thickness variable, perhaps not exceeding	24

The combined thickness of the Lower Estuarine Series and the Northampton Sand has been estimated not to exceed 40 ft. in this part of the Midlands,[2] but if the records of 30 ft. of ironstone and sandstone from a well at Waltham[3] are accurate, this may be rather an underestimate.

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[1] By C. B. Wedd.

[2] "Geology of the South-west part of Lincolnshire, &c." *Mem. Geol. Surv.*, 1885, p. 45.

[3] *Ibid.* 50.

Palaeontologically the Northampton Sand, as the approximate equivalent of the Midford Sand, is held to include part of the Jurensis Zone, the Opalinus Zone, and some portion of the Murchisonae Zone.[1] The marine Lincolnshire Limestone which is locally intercalated between the Lower and Upper Estuarine Series, was assigned by Prof. Judd to the Sub-zone of "*Ammonites Sowerbyi*."[2] But owing to Mr. S. S. Buckman's narrower restriction of the specific term *Harpoceras sowerbyi*,[3] the horizon of this limestone was subsequently included in the upper part of the Murchisonae Zone. Moreover Mr. W. H. Hudleston, while accepting the bulk of the limestone as belonging to the lower or Murchisonae Zone, regards its upper part in the neighbourhood of Great Ponton as denoting a high horizon of the Inferior Oolite.[4] For our present purpose, however, we have to deal only with the lower part of the limestone which may all be regarded as belonging to the Murchisonae Zone.

Northampton Beds (*Northampton Sand and Lower Estuarine Series*).—Of the broad expanse of these beds around the chief tract of Lincolnshire Limestone, the lower sandy and ferruginous member constitutes nearly the whole, while the estuarine beds, not separately mapped, make merely a narrow fringe below the limestone. The outcrop of the relatively durable Northampton Sand capping the Upper Lias Clay produces a conspicuous escarpment. But its strata are seldom exposed except in artificial sections, and as the raising of the ironstone from these beds was abandoned in this district over 30 years ago, the old workings are now overgrown. The only sections actually visible in 1906 were at the Stonesby brick-pit and in a small opening in Croxton Park, but during the previous survey much information was obtained from the ironstone workings near Waltham-on-the-Wolds and was incorporated in the memoir on Sheet 70.[5] In that memoir the general succession is stated as follows :—

		ft.
"Lincolnshire Limestone	up to	20
Shaly sandstone	„	1
Soft yellow sand	„	3
Bluish-grey laminated clays	about	13
Ironstone (best red stone)...	„	3
Ironstone ('curly'), a mass of fossil-casts	„	3
Ferruginous 'sandstone'	seen for	5."

Prof. Judd has shown that in the ironstones of this group an original carbonate of iron, usually exhibiting oolitic structure, is

[1] H. B. Woodward "Jurassic Rocks of Britain," vol. iv. *Mem. Geol. Surv.*, 1894, p. 167.

[2] "Geology of Rutland, &c.," p. 39.

[3] "A descriptive Catalogue of some of the Species of Ammonites from the Inferior Oolite of Dorset." *Quart. Journ. Geol. Soc.*, vol. xxxvii., 1881, p. 602.

[4] "British Jurassic Gasteropoda," Pt. I., No. 4, "Gasteropoda of the Inferior Oolite." *Pal. Soc. Mon.*, 1890, pp. 196 and 215. *See also* H. B. Woodward, "Jurassic Rocks of Britain," vol. iv., 1894, p. 173.

[5] "Geology of the South-west part of Lincolnshire, &c."

replaced under superficial conditions by a brown sesquioxide of iron. In fact this ironstone very closely resembles that of the Marlstone. Of the unweathered rock Prof. Judd states that it "consists of a mineral composed mainly of carbonate of iron (but containing disseminated through it grains of quartz and siliceous oolitic concretions) which is coloured, usually of a bluish or greenish tint, by minute quantities of other ferrous compounds. The rock usually exhibits only slight traces of the planes of bedding, and although it is traversed by joints, yet these . . . are so little open that the stratum is almost constantly water-bearing, and cannot be quarried without blasting."[1]

Though some beds of the Northampton Sand are locally crowded with fossils, its generally unfossiliferous nature furnishes a rough distinction between it and the Marlstone. The only fossils obtained from it during the resurvey were the few lamellibranchs and brachiopods in the Croxton Park section, described below (p. 59).

The above-quoted section of the Lower Estuarine beds at the Waltham ironstone workings fairly represents their sequence in the southern and western part of their outcrop; and although the upper sand was not seen along the northern outcrop, there is no reason to suppose that it is absent there. But the series is essentially variable in detail. In the previous memoir[2] it is mentioned that from "a trial hole at the edge of the [Lincolnshire] Limestone, one mile NNW. of Waltham Church . . . was thrown out a quantity of soft ferruginous sandstone and nearly black shale (Lower Estuarine)."

DETAILS.

Northampton Beds.—In its most westerly position the Northampton Sand forms an outlier capping a hill of Upper Lias clay and almost completely concealed by drift, ¼ mile E. of Goadby Marwood. Some doubt was expressed in the previous memoir[3] as to whether this outlier might not really be the Middle Lias Marlstone brought up by a fault. But it has previously been shown that between Eastwell and Scalford the Upper Lias clay comes on in normal succession above the Marlstone (p. 52), and the sequence continues upward to the Northampton Sand, as shown on the old map. Though the limits of the outlier are rendered uncertain by the drift which covers it on all sides but the west, there is evidence that it has a greater northerly extension than is indicated on the old map. Ironstone débris is plentiful along the brow of the hill northward of Goadby Gorse, and a trench cut in 1906 for piping water from a pond 120 yds. NE. of the road to Eastwell, showed thin weathered ironstone with obscure casts of fossils.

The main outcrop of the Northampton Beds sets in on the east side of the drift-filled valley along which the Waltham Branch of the mineral-railway runs, but is at first drift-covered. A series of small faults brings up the ironstone again.

The following details of sections which were formerly exposed in the neighbourhood of Waltham are reproduced, along with the accompanying figure (Fig. 5), from the previous memoir[4]:—

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[1] "Geology of Rutland, &c." *Mem. Geol. Surv.*, 1875, p. 117.
[2] "Geology of SW. Lincolnshire, &c.," p. 54.
[3] *Ibid.*, p. 13.
[4] *Ibid.*, pp. 47–49.

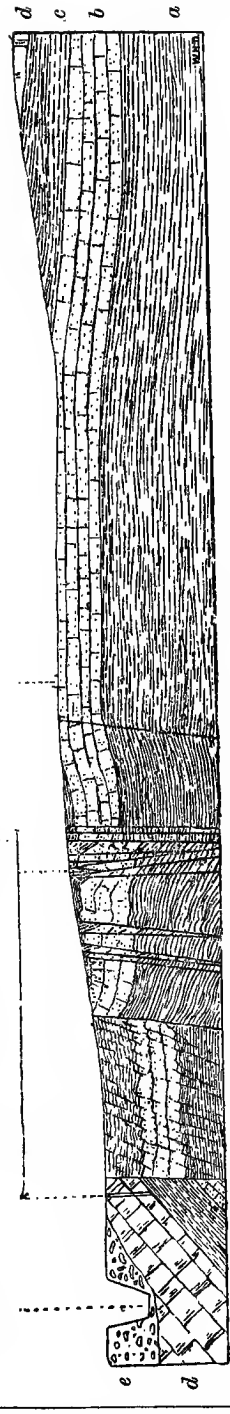

FIG. 5.—SECTION ALONG THE WORKING TRENCH OF THE HOLWELL IRON COMPANY NEAR WALTHAM-ON-THE-WOLD (EXTENDED TO OOLITE). (From "*Geology of SW. part of Lincolnshire, &c.*")

Scale :—8 chains to an inch horizontal ; 80 feet to an inch vertical.

e Boulder Clay.
d Lincolnstone Limestone.
c Lower Estuarine Clays.
b Ironstone and "Sandstone."
a Upper Lias Clay, position not known.

"In the railway cutting on the NE. side of the road near Waltham Station the Lincolnshire Limestone is found with a westerly dip, but much broken and disturbed. At the extreme end of the cutting, 13 chains from the bridge, grey shaly clay is brought up from beneath the limestone with a dip of 40° to W. 11° N. ; this is faulted against a face of limestone with an apparent dip of 35° to W. 10° S., the fault itself trending E. 40° S., or nearly at right angles to the railway cutting.

"In the direct line of the cutting and five chains beyond its present termination is a trial hole, which, according to the foreman, pierced limestone, clay, and ironstone, and the ground immediately beyond is thickly strewn with fragments of ironstone which is probably faulted up against the limestone. In the fields to the north the Boulder-clay comes on, but the excess of limestone fragments in one part of a field and of ironstone in the rest points to a continuation of the faulted junction ; for if there were no fault, a band of clay-land would intervene between the two.

"An examination of the cutting for the Holwell Iron Company's tramways, bearing SE. from the railway bridge,[1] shows that the whole area is shattered by faults of small individual but considerable aggregate throw. They all bear N. 2° W., and with one or two exceptions have downthrows to west. In the short intervals between the faults, often only a few yards, the beds are tilted at angles varying up to 45°, so that in the face of the workings the ironstone presents a series of sharp ridges, while the interspaces are filled up by the clays of the Lower Estuarine Series.[2] In one case a trial hole was sunk 11 ft. in

[1] The cutting has been filled in, but appears to have run along the SW. side of the by-road trending SE. from the railway bridge.

[2] The structure here described is similar to that which is frequently seen at the junction of the Marlstone with the overlying Upper Lias clays (*see* pp. 46, 48, 52).

stiff clay, the side of the pit being but six inches from a fault that brought the rich ironstone nearly to the surface. The ultimate effect of these faults is to bring down the Oolite at the railway, far below the position which the plane of the main mass would occupy. Its western limit is masked by drift; it may be a fault or a natural boundary. Its eastern limit is certainly a fault, breaking an anticlinal axis, as shown in Fig. [5], for an open well was sunk at the offices of the Holwell Company's works, five chains from the centre of the railway,[1] passing through 19 feet of limestone, while the cutting a few yards further east shows Lower Estuarine Clay dipping eastward under limestone débris, and faulted against the ironstone.

"At a point about eight chains from the turnpike road a small mass of the limestone is faulted down between the clay and ironstone; it is too small to be shown on the map, as its breadth along the working face is only about 25 ft. Nearer the turnpike road there are several faults heading in the opposite direction, with downthrows on the eastern side, making with the other a broken synclinal (*see* Fig. [5]).

"This congeries of small faults is a serious inconvenience in working the ore, as all the clay between the ridges has to be removed, and much of the worthless sandstone also, in order to reach the profitable portions.

"In the field to the east of the main road a trial hole shows ironstone nearly horizontal, and in the succeeding field it passes beneath clay and limestone gently eastward.

"The cutting of the Staveley Iron and Coal Company to the SW. of the other is in some respects clearer, and in it the fault which brings down the Oolite on the west is actually visible at a distance of about 15 chains north-west from the main road.

"The fault crosses the line of tramway obliquely, and bears a little east of north; on the west side there is limestone, disturbed and broken; on the east side the Estuarine Clays are seen dipping rapidly beneath 3 ft. of yellow sand passing up into shaly sandstone (1 ft.), and succeeded by broken limestone; the clays are then faulted up again, and a little farther east the ironstone is brought to the surface.

"At the end of this tramway, by the new bridge under the main road to Waltham, the cutting is 12 ft. deep, showing the following section:—

	ft.
"Brown sandy soil, with lumps of ironstone	4
Good ironstone	3
Brown 'sandstone' (perhaps a decalcified ferruginous limestone)	5

"The beds here are undisturbed, and nearly horizontal."

As at the time of the former survey this ground presented much greater facilities for its elucidation than it now does, the faulted boundary between the Northampton Beds and the Lincolnshire Limestone, in the immediate neighbourhood of the old Waltham workings, is reproduced from the old map. It approximately defines the westward limit of abundant ironstone material in the soil; but owing to the intensity of faulting throughout a rather wide belt of ground (*see* Fig. 5), this line cannot be regarded as anything more than a rough generalization.

The mapping of this faulted tract presents many difficulties, and while it was found, during the recent survey, that a N–S. fault throwing down the limestone on the west could be traced for some distance southward by the surface-indications, no evidence was forthcoming for the presence of the two cross-faults shown on the old map near Waltham; and as the southerly termination of the limestone there may be brought about by the continuation of a north-and-south fault, this simpler interpretation of the ground has been adopted.

At Waltham, as recorded in the former memoir,[2] the base of the Northampton Sand crops out above Upper Lias on the green between the Church and the Royal Horse Shoe Inn. In the yard of the inn a well "was dug and bored to a depth of 40 yds. in blue clay without finding water; while at a cottage just west of the yard water was found in ironstone at a depth of 14 ft. Here, therefore, the ironstone is faulted against Upper Lias." The fault is certainly one of the group of N–S. dislocations described above, while an adjacent and nearly parallel line of fracture appears to have displaced the limestone against the ironstone a few yards further W. Moreover it is probable that small faults of

[1] A pump is marked in this position on the 6-inch map.
[2] "Geology of SW. Lincolnshire," p. 50.

this group, with westerly downthrow, continue southward as far as the Rectory, to judge from the low level of the base of the Northampton Sand on the westward slope, and the presence of pale blue and yellow clay apparently belonging to the overlying Lower Estuarine Series, in the neighbourhood of the main road, slightly below the level of the Northampton Sand east of the road.

South of the rectory the base of the Northampton Sand is rather obscure, but thence eastward it can easily be traced by its escarpment nearly as far as Stonesby. In the brick-pit at Stonesby the ENE. fault shown on the new map is seen to throw down, on the N., 14 ft. of unfossiliferous brown ironstone and ferruginous sandstone against the higher beds of the Upper Lias. Further E. the same fault appears to cut out the Northampton Sand on the S. side of Stonesby, until a tongue of these beds, with well-defined outcrop, enters the E. margin of the district S. of the main road.

North of Stonesby soft yellow sand belonging to the upper part of the Lower Estuarine Series is thrown out from rabbit-burrows immediately below the principal outcrop of the Lincolnshire Limestone; while near the footpath about 300 yds. N. of Stonesby Church a small section showed thin flaggy oolitic limestone overlying 2 ft. of yellow, red-streaked sand, with pale blue clay below, a sequence corresponding, so far as it goes, with that at Waltham. The outcrop of these soft strata is generally marked by a slight and narrow depression skirting the limestone; and ponds on this horizon expose at intervals 3 or 4 ft. of pale blue and whitish silty clay.

The narrow strip of Lincolnshire Limestone running N. from Waltham is apparently cut out W. of Ling Cover by a cross-fault which brings up the Northampton Sand on its N. side. The broad northern tract of these beds, exceeding 560 ft. O.D., terminates northward in an escarpment above the Upper Lias Clay. This escarpment makes a very conspicuous feature, until in Croxton Park it is breached by the picturesque wooded valley which with its many branches cuts deeply into the Upper Lias, the numerous springs which feed its stream issuing from the base of the Northampton Sand.

East of the valley a north-easterly fault appears to cut out the Northampton Beds, as no trace of them could be found on the slope below the Lincolnshire Limestone, while the almost continuous presence of blue clay in the shallow cutting along the Grantham road suggests that the Upper Lias extends right up to the limestone, in which, north of the road, a high dip and signs of disturbance were noted.

The only clear exposure of the Northampton Sand in the northern tract is in a little pit at the base of the series in Croxton Park, 680 yds. due W. of the Park House, at the edge of the small valley 500 yds. S. of Windmill Hill. This pit afforded the following details:—

	ft.	in.
Ferruginous loamy soil and weathered disintegrated ironstone ...	6	0
Soft ochreous ironstone full of fossils, including a rhynchonellid, *Terebratula trilineata* Tate and Blake (abundant), *Lima sp.*, *Modiola* cf. *cuneata* J. Sow. (abundant), *Pecten* (*Amusium*) *paradoxus* Goldf.	1	6
Ochreous sandy clay, reddish at top	1	0

Here the fossiliferous ironstone appears to be the actual base of the Northampton Sand, the clay below being probably the stained and weathered top of the Upper Lias, with which some of the overlying sandy material has become incorporated. The fossils were in the form of casts covered with a dark brown film of the concentrated iron-ore which produces the familiar cellular appearance of the rock.

Lincolnshire Limestone.—The lower part of the Lincolnshire Limestone exhibits a variable sequence of massive and thin-bedded, platy and rubbly limestones, ranging in structure from oolite to close-textured limestone with a few scattered ooliths or none at all. Amongst these are bands of hard shelly ragstone and beds of coralliferous and calcitic rock, often rather marly. Its usual colour near the surface is white or creamy, but when unaltered by surface conditions it is blue or grey. Intercalated in its lower part are occasional thin bands of grey marl or clay and sandstone, while the lowest beds are described as consisting usually of fissile sandy limestone, and may be the local equivalents of the Collyweston Slate.[1]

[1] "Geology of SW. Lincolnshire, &c.," p. 52.

The abundant marine fauna consists largely of lamellibranchs, with gasteropods, brachiopods, echinoderms and corals. As a comprehensive list of the fauna of the limestone, embracing a much wider area, was given by Mr. A. J. Jukes-Browne in the previous memoir on Sheet 70 ("Geology of the SW. part of Lincolnshire," &c, pp. 131–6), and as no systematic collecting has been done in the limited tract falling within the area of the present map, the reader is referred to that publication for the details of the palaeontology, which it is unnecessary here to repeat.

In the faulted strip of limestone extending northward from Waltham the only exposure now to be seen occurs at the termination of the railway-cutting beyond Waltham Station, where compact buff shelly limestone, much shattered and with a high westerly dip, is faulted against the Estuarine clays, as mentioned above (p. 57).

The following section recorded in the previous memoir[1] was taken by Mr. Skertchly in 1870 in a quarry 1 mile NNW. of Waltham Church :—

	ft.	in.
Soil	0	6
Rubble limestone	1	6
Compact limestone	0	6
Marly bed	0	6
Limestone (Ragstone with disseminated oolitic grains and shell-fragments)	2	6
Clay, blue and marly	0	6
Limestone, compact, very hard, blue, without oolitic grains, seen to	2	0
	8	0

At the S. end of this tract of limestone a well sunk near a cottage on the N. side of the road, 250 yds. WNW. of Waltham Church, but now filled in, proved[2] :—

	ft.
Loamy ratchel	10
Limestone ... ... from 7 ft. to	10
White shaly clay	—

The chief tract of this limestone forms a broad, slightly furrowed plateau stretching through Croxton Park to Waltham and Stonesby.

The limestone of this tract terminates in a decidedly poor escarpment, perhaps because no great thickness of the rock is present, and because it is weakened by the intercalation of soft shaly beds near the base. Immediately east of Waltham indeed, the limestone comes on with a surprisingly slight and gradual rise; but the ground there reaches the highest elevation of the whole district (573 ft.) and forms the central watershed of a small radial drainage; and on watersheds in general the surface-features of hard and soft beds are often but little differentiated. When traced north-eastward towards the valley in Croxton Park, the limestone gradually develops a more decided escarpment, and a similar though smaller escarpment is developed along its southern boundary on approaching the southerly drainage.

The large quarry 5 furlongs E. of Waltham Church, as described in the previous memoir, still affords the only section in the main outcrop of limestone, but it is now rarely worked. The following are the details of the beds[3] as exposed in 1883 :—

[1] "Geology of SW. Lincolnshire, &c.," p. 54.

[2] Information by Mr. J. T. Whitfield, well-sinker.

[3] "Geology of SW. Lincolnshire, &c.," p. 54.

	ft.	in.
" 12. Soil and rubble	3	0
11. Beds of compact earthy limestone, with a slight tinge of pink in some places	7	0
10. Course of hard splintery limestone	0	4
9. Hard compact earthy limestone, very shelly in places, in three courses with seams of calcareous shale	4	0
8. Coarse-grained oolite (Ragstone)	1	9
7. Hard rough oolitic ragstone, very loose and rubbly at the base	1	6
6. Yellow laminated micaceous sand	1	0
	18	7

" In an old working at a lower level lower beds were seen :—

7. Rough oolitic ragstone	1	6
6. Hard yellow micaceous sandstone...	1	0
5. Loose sandy and shaly limestone	1	3
4. Shelly and oolitic limestones	2	0
3. Compact earthy limestone	1	6
2. Grey shaly clay	1	0
1. Very hard compact blue-grey limestone	1	6
	9	9 "

The lowest bed of the above section must be very close to the base of the limestone. The following few species were lately obtained from the middle beds there seen :—*Ceromya* cf. *bajociana* d'Orb., *Cyprina ?*, *Lima* (*Plagiostoma*) *pontonis* Lycett, *? Natica cincta* Phill.

A slight depression beginning SW. of Bescaby increases near that place to a conspicuous valley descending in an ENE. direction. In it a strong spring (Hamwell Spring) issues from the limestone and is regarded as the source of the River Eye. The existence of the spring, and probably of the valley itself, at Bescaby is attributable to the presence of a band of grey clay, some 2 ft. of which is seen here and there in the valley-bottom. But for the slightly synclinal structure of the tract, the clay might be regarded as belonging to the Estuarine Series below the limestone ; it is, however, more probably equivalent to the clay band seen near the base of the limestone in the Waltham quarry. Close to the spring was a small exposure showing a few inches of light grey flaggy and slightly oolitic limestone with small oysters and a species of *Pecten* (*Camptonectes*). A smaller parallel valley a little further S. probably owns its origin to the same cause.

The structure of the ground at Stonesby presents difficulties ; the fault seen in the Stonesby brick-pit (*see* above, p. 53) makes a satisfactory boundary line for the limestone on the south and obviates the necessity for the hypothetical N-S. fault shown on the old map. Then, there seems to be a cross-fault immediately W. of the village at right angles to that of the brick-pit, for on the opposite sides of a narrow valley with a spring at its head the Northampton Sand and the limestone lie at the same level. The real difficulty concerns the relationship of the limestone on which Stonesby stands to the main mass further north, as the long tongue of the Estuarine beds wedged in between them is not due to the excavation of a valley through the limestone. The junction on the N. side of the tongue is a natural one, at any rate as far E. as Stonesby village. The junction on the S. side is very uncertain, both as regards direction and position, but it seems to imply faulting of some kind. The vertical displacement however can be only small.

C. B. W.

CHAPTER VIII.

GLACIAL DEPOSITS.[1]

GENERAL ACCOUNT.[2]

As briefly mentioned in the first chapter of this memoir, the Glacial deposits form an important element in the geology of the map, and their presence has determined all the minor features of the physiography. They are of peculiar interest inasmuch as they represent the northern margin of the great sheet of drift which covers the eastern part of the Midland plain, for in all the country to the northward and north-westward up to and beyond the Yorkshire border, the Glacial drifts are represented only by isolated patches, difficult of correlation, in a generally driftless area.

Though the deposits vary from place to place in their materials and structure, including unstratified boulder-clays of diverse composition along with irregular beds of stratified gravel, sand and loam, it is only in the south-western part of the district, along the valley of the Wreak and its branches, that a definite order of superposition can be traced in them. In this quarter, as described by Mr. Fox-Strangways[3], the lowest bed of the series consists of sand and gravel, obscurely seen in a few places in the Wreak valley between Kirby Bellars and Rotherby. This 'Older Sand and Gravel' is apparently overlain, in the same valley, by the 'Older Boulder Clay'—"a stiff marly clay of a variegated red and bluish-grey colour, with small pebbles of quartzite and other rocks, but containing few, if any, large boulders, nor any derived from the Chalk or Oolite." Above this boulder-clay there occurs a fairly continuous stratified deposit—'The Quartzose Sand'[4]—consisting largely of gravel and sand containing much coal detritus, and in the lower part of the Wreak valley passing into a laminated clay or brick-earth.

Traces of some part of the above succession were also detected in the eastern prolongation of the same valley, E. of Melton Mowbray; but it appears to be confined to this valley and was not recognizable in other parts of the district, where boulder-clays of different composition, as will presently be shown, seem to merge laterally into each other (pp. 76–9). Whether the succession was produced by local conditions peculiar to the area in which it occurs, or whether it represents the surviving remnants of an originally wider-spread sequence of which the lower members have been elsewhere destroyed during the later glaciation, is a question on which there is room for difference of opinion, as the evidence is not conclusive for either view. Adopting the latter hypothesis, Mr. R. M. Deeley[5] has classified the drifts of this and neighbouring

[1] By all the authors of the memoir.

[2] In part reprinted, with additions and alterations, from the "Summary of Progress of the Geological Survey for 1906," pp. 21–25.

[3] "The Geology of the Country near Leicester (Sheet 156)" *Mem. Geol. Surv.*, 1903, pp. 43–56.

[4] A term adopted from Mr. R. M. Deeley's paper referred to below.

[5] "The Pleistocene Succession in the Trent Basin." *Quart. Journ. Geol. Soc.*, vol. xlii., 1886, pp. 437–480.

districts under a complex scheme of three major divisions and eight subdivisions; but we have been unable to follow the details of his classification in mapping the country. It is evident that there were changes of condition during the progress of the glaciation, giving rise to differences in the structure and composition of the deposits; but the local variations thus produced appear to differ from place to place, and to be too limited and uncertain to afford the basis for a general scheme of classification.

Throughout the district, the predominant member of the Glacial series is the massive sheet of boulder-clay which from its composition and from its continuity southward and eastward is identified as the prolongation of the Chalky Boulder Clay of the Eastern Counties. This deposit overlies the 'Quartzose Sand' of the Wreak valley and forms the surface of the broad dissected plateau to the northward, over which the Romans drove the Foss Way. It is usually a very tough stony clay, greyish or bluish when fresh but more or less yellow in weathered exposures, bountifully sprinkled with rock-fragments of all sizes, among which the relics of the harder portions of the Lias, Oolites and Chalk, and of the Bunter Pebble Beds predominate, though in ever-varying proportions. It also contains a small, yet conspicuous admixture of boulders from more distant sources, especially from the limestones and sandstones of the Carboniferous system; and a few igneous rocks occur among the larger boulders, mainly of basaltic type, such as are sometimes associated with the Carboniferous strata of Northern England, while one or two abnormal boulders were noticed which may have come from the Lake district or some equally distant source (pp. 80, 83).

Where not removed by the post-glacial denudation, this great sheet of boulder-clay, levelling up all the minor inequalities of the old surface and attaining in places a thickness of at least 150 ft., overlies all the Lower Lias south of the Marlstone spur, but thins out or is broken up into irregular tongues along the Marlstone outcrop. Where the Marlstone spur terminates westward, the plateau of boulder clay sweeps northward round the end of the ridge and crosses the Lower Lias in an elevated belt, gradually narrowing and becoming much dissected, but traceable up to the northern margin of the map near Clipston. In this belt, however, though the continuity of the plateau is maintained, the dark-blue boulder-clay loses its chalky character and merges gradually into a red drift of different aspect, derived mainly from the Triassic rocks.

South of the high Marlstone spur, the effect of the boulder-clay is partly to fill up the Lower Lias depression, so that the country falls away very gradually southward from the steep northerly escarpment of the Middle Lias, and no pronounced feature is developed along the southern edge of the Marlstone. Between Eastwell and Stathern there appears to be a deep gap in the escarpment which is entirely filled with drift. The same conditions recur a little westward of Long Clawson Station; and it is curious to find that in these cases the drift ends off along with the 'solid' escarpment, and does not encroach upon the low country beyond it.

Still more striking is the position of the boulder-clay in the elevated belt which, as above-mentioned, runs northward from the end of the Marlstone spur at Old Dalby. Between this place and

Owthorpe the plateau occupied by the boulder-clay breaks off suddenly eastward in a steep feature, of which the crest is usually at least 100 feet above the base. The feature appears to be an actual escarpment of the boulder-clay, for its direction is oblique to the strike of the underlying Lower Lias.

East of this feature, in the great triangular stretch of low ground —the 'Vale of Belvoir' of our Index-map, Fig. 1 (p. 2), six miles broad between Owthorpe and Stathern—the Lower Lias is everywhere close to the surface, the only indication of drift being a sprinkling of transported stones or an occasional 'pocket' of gravel 3 or 4 ft. in depth. Yet although this low ground has yielded nothing that could be definitely recognised as boulder-clay, there is evidence that it has participated in the glaciation equally with the surrounding country. One proof of this is that in the ironstone-working close to the crest of the Marlstone escarpment, half a mile NW. of Wartnaby, already referred to on p. 48, at 500 ft. above O.D., the protruding bosses on the uneven surface of the ironstone beneath the boulder-clay showed ice-scratchings that prove a movement of the ice from N10°W. toward S10°E., *i.e.*, a movement *from* the present low ground and *across* the high escarpment at a right angle; (*see* Fig. 6 and p. 70–1 for details).

From this and other evidence of similar character, it is clear that the Vale of Belvoir has lain within the area of glaciation. But whether it was once covered by a sheet of drift which has been subsequently removed by erosion, or whether it is a tract upon which little or no drift was ever deposited, is still an open question. That the boulder-clay has undergone very extensive denudation is shown not only by its truncation along the escarpment, but also by its deep trenching by all the streams. These have developed wide valleys that are often cut completely through the drift, and to some depth into the Lias also. But it is difficult to imagine any conditions under which the drift could be systematically removed from the whole of the Vale of Belvoir, and yet remain in its present quantity on the plateau. Probably, therefore, the Vale is an area where, from the original shape of the ground and its relation to the ice-movement, there was very little accumulation of drift during the glaciation. The vast amount of Liassic material that has gone to the making of the Midland boulder-clays shows that there must have been extensive tracts of Lias which were being stripped during the glaciation. On the other hand, the thickness of the drift overlying many wide areas of the Lias must have protected these particular areas from glacial erosion—at least during the later stages of the glaciation —a protection probably obtained at the expense of tracts that were being stripped.

During the course of the glaciation in this as in most glaciated areas, there appear to have been changes in the direction of the major ice-flow, and the striæ at Wartnaby indicate only one—probably an early—phase of the movement. Thus, at the only other place in the district where glacial striæ have been observed, *viz.*, in the Stanton tunnel on the Midland Railway (p. 77), the ice-scratchings on a surface of Lias limestone were approximately NE.—SW.; and this direction nearly agrees with the general travel of the transported material.

In mapping the boulder-clay it is found that certain belts are distinguishable by the predominance of débris of a particular kind; from which, however, must be excluded the Carboniferous boulders, for though relatively few, these are ubiquitous, evenly distributed, and never clustered.

South of the Marlstone spur, chalk and flint are widely distributed and locally abundant, but still tend to predominate in distinct areas. The Lower Oolite material, being nearer its source, shows a stronger tendency to local segregation, and preponderates in a narrow belt extending, and also expanding, south-westward from the Lincolnshire Limestone outcrop of Waltham to the neighbourhood of Welby and Sysonby; while on the NW. side of this belt, in the neighbourhood of Chadwell and Scalford, the boulder-clay is extremely chalky.

The same predominant direction of transport is indicated by the upland drift west of the Vale of Belvoir. In the north part of this tract the boulder-clay has a reddish matrix, and contains a large admixture of Keuper Marl and Rhætic shales; east of Widmerpool its matrix is dull-blue, and chalk is abundant; west of Old Dalby, boulders of the ferruginous Marlstone and of oolitic limestone are present in large numbers; while brown flints, and pebbles from the Bunter, occur throughout. The distribution of the material appears to indicate, in the north of the area, an ice-movement from a direction somewhat N. of NE. swinging to somewhat E. of NE. in the southern part, as expressed in the diagram, Fig. 9, p. 79.

With the exception of a few isolated streaks and pockets of loam, sand, and gravel, there is a remarkable absence of stratified drift on the boulder-clay plateau until we approach its western margin, where such deposits begin to assume importance. Along this margin, from Plumtree to Stanford, strips of sand and gravel emerge at frequent intervals from beneath the boulder-clay, and occasionally also overlie it or apparently replace it altogether. In the otherwise driftless country to the north-westward, gravelly deposits frequently cap the highest ground, *e.g.*, at Wilford Hill, Bradmore, and East Leake Hills; and a thin gravelly wash is spread very generally over the lower ground, greatly modifying the character of the soil over the Keuper Marl, and causing much difficulty in the mapping. Some of these gravels are certainly of glacial age and origin, while others appear to mark the rapid erosion of the country during the melting of the ice, and afford a link between the Glacial deposits proper and the oldest flood gravels of the existing valleys, this succession being best displayed in the basin of the Fairham Brook, between Bunny and Widmerpool.

On the outer slope of the Marlstone escarpment S. of Belvoir Castle, and in the deep valleys of the Devon and its little tributaries which lie just within this part of the escarpment, there is a considerable development of stratified sand occurring under conditions difficult of explanation. On the outer slope, this sand is found in isolated patches at about 300 ft. above O.D., but in the valley of the Devon it forms a wide strip rising gradually from about 200 ft. to 300 ft. above sea-level, and sends off branches to form still higher terraces on the slopes of the narrow side-valleys,

often masked by the rubbly downwash of the hillsides (*see* pp. 72–3, and Fig. 7). Its relation to the Chalky Boulder Clay is not clear, as in most cases the two deposits do not occur together; but it appears probable that the sands have accumulated in a marginal sheet of water at the edge of the ice during the melting of the glacier which occupied the Vale of Belvoir.

The irregular terraces of flood-gravel occurring on the flanks of the valleys of the Soar and Wreak, though later than the actual glaciation of the district, are, as compared with the recent alluvium, of relatively high antiquity. As mentioned in Chap. I., they probably date back to the closing phase of the Glacial period, during which there must have been very rapid erosion of the boulder-clay, so that the main valleys cut into it soon attained to almost their present dimensions. But these gravels are distinctly associated with the present drainage-system, and they will be dealt with under a separate heading at the end of this chapter.

G. W. L.

DETAILS.

In describing the Glacial deposits in further detail, we shall deal first with the main mass in the SE. part of the map (surveyed by Mr. C. B. Wedd); its northward lobe-like extensions (surveyed by Mr. Lamplugh and Dr. Gibson); and its prolongation westward (surveyed by Mr. C. Fox-Strangways). The northward extension of the drift-plateau in the NW. part of the map (surveyed by Mr. R. L. Sherlock and Mr. B. Smith) will then be described, together with the isolated and somewhat indefinite remnants on the lower ground E. and W. of the plateau.

Three types of boulder-clay may be recognized in the SE. district:—(1) the Chalky Boulder Clay of the general type above described, which practically monopolizes the surface of the drift-plateau; (2) a leaden-grey clay of Lower-Liassic or immediately local origin, with very few rock-fragments, among which Cretaceous and Oolitic materials seem not to occur; and (3) a red, laminated, silty clay, apparently derived from the Keuper Marl, often much contorted, and containing still fewer stones which consist, in the one clear section where this clay is exposed, exclusively of Bunter pebbles and fragments of Keuper 'skerries.'

With the boulder-clays are intercalated some sands and gravels containing abundant pebbles from Cretaceous, Jurassic, Triassic and Carboniferous formations, with a few worn fragments of igneous rocks.

The boulder-clay rises from the valley of the Wreak and Eye on both sides to well above the 400 ft. contour, and in a few places attains to over 500 ft. It sweeps over and obliterates the southern edge of the high-lying spur of Marlstone, filling the transverse valleys and profoundly modifying the pre-glacial physiography. Along the downward slope to the Eye valley, where it lies thickest, its depth was proved to exceed 168 ft. at Sysonby House, a mile N. of Melton Mowbray. Around Melton, it descends into the valley, passes under the alluvium, and forms the rising ground on the south. In this quarter it evidently fills a hollow in the Lower Lias, possibly the southern prolongation of an old valley with drift-filled branches which break the Middle Lias escarpment at Stathern and at Scalford; for, both E. and W. of Melton, the Lower Lias rises again into the floor of the present valley, the drift-filled space between the visible outcrops in the valley being about 2½ miles wide.

The main plateau is composed almost entirely of boulder-clay; but stratified drift, consisting of gravel, sand and silt, crops out along the flanks of the Eye valley from within or beneath the boulder-clay in a manner suggestive of its sporadic occurrence at a definite horizon equivalent to the more continuous belt farther westward, along the valley of the Wreak (*see* p. 74). This sandy drift generally lies between the 200 ft. and 300 ft. contours, and is rarely seen except along the slopes of the valleys; but at New Guadaloupe, a mile S. of Melton Mowbray, it reaches the surface on relatively high ground, some 85 ft. above the valley.

The original surface of the boulder-clay appears to have formed a smooth gently undulating plain having a slight general fall towards the north-west, but it is now deeply scored by post-glacial drainage-valleys, which strike back far into it, breaking it up, in the neighbourhood of the broad Eye and Wreak valley, into long round-backed ridges.

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A large brick-pit on the northern outskirts of Melton Mowbray, S. of the G. N. Ry., 400 yds. E. of the Station, affords an interesting section showing the relationship of drifts of different composition. At its N. side it exhibits from bottom to top a leaden-grey clay, about 20 ft. thick, evidently derived from the Lower Lias, but thoroughly re-constructed, and including among its very scanty extraneous material occasional fragments of Marlstone, rare Bunter pebbles, and a greenish chloritic sandstone of uncertain origin. Separate from this grey clay, but reclining against it at a steep angle in the S. side of the pit and occasionally wisped into it at their junction, is a smaller contorted mass of red laminated silty clay, evidently derived ultimately from the Keuper Marl, perhaps as a re-deposited alluvial sediment. In this, only a very few small stones were found, all being Bunter pebbles or fragments of Keuper 'skerry.' The upper part of the red clay was obscured by talus at the time of the survey; but a ledge excavated in the top of the pit above it exhibited beds of different character, the lowermost consisting of clean yellow sand, partly current-bedded, partly undulating, with a band of grey loam in it near the top. The surface of the sand declined eastward towards the neighbouring valley, and passed under a wedge of contorted and intermixed red and grey clays, similar to those below, but apparently free from stones; the red clay predominating, and the grey usually lying uppermost. Among the red clay, but dove-tailing into the sand, were two thin bands of mixed stony clay, with abundant fragments of Lincolnshire Limestone and some chalk and flint. The eastward prolongation of the section was obscure, but after a few feet, light blue Chalky Boulder Clay was seen to set in at the top, over all the beds above described; while at the W. end of the pit the sand reached nearly to the surface and was overlain unevenly by gravelly soil, either rainwash or the weathered remnant of a gravel-lenticle associated with the sand. No fossils except those derivative from the Secondary rocks were found in any of the beds

The deduction to be drawn from the general evidence in the Wreak valley is that the lowest Glacial deposits are of local derivation, consisting partly of the crushed and re-constructed subjacent Lower Lias and partly of Keuper material assorted and re-deposited by water; and that subsequently the area was invaded by the glaciating agent which brought in the Chalky Boulder Clay and ploughed up some part of the underlying drift.

In the adjoining section of Barnes's Brick-pit, the higher members of the above section appear to have been removed by post-glacial erosion, and the grey clay, partly stained to a purplish hue, passes directly under alluvial deposits (*see* below, p. 88). The grey clay here yielded, besides occasional fragments of Lower Lias limestone, a small well-striated boulder of chloritic sandstone such as was found in the same clay of the larger pit.[1] We were informed that the clay with stones continues 12 ft. lower and rests upon clay without stones. But there is no definite evidence to what depth the Glacial deposits descend here. Prof. Judd mentions that the drift "near here [the Melton brick-pits] attains a thickness, as proved by well sections and borings, of not less than 200 ft."[2] It is practically certain however that this statement must have reference to the thickness on the higher ground N. of the town. In the bore-hole 200 yds. W. of the Station (*see* Appendix I, p. 106), at about the same level, the base of the drift appears to have been reached at 38 ft. below the surface.

The two lobes of drift previously referred to, burying the old transverse valleys at Scalford and Stathern, at first sight suggest the possibility of a pre-glacial through-drainage across the Marlstone outcrop. But a consideration

[1] These sections were examined by Prof. J. W. Judd, who classed the sands and clays below the Chalky Boulder Clay as pre-glacial ("Geology of Rutland," *Mem. Geol. Surv.*, 1875, p. 243); and they were further described by Mr. R. M. Deeley ("The Pleistocene Succession in the Trent Basin," *Quart. Journ. Geol. Soc.*, vol. xlii., 1886, p. 455).

[2] "Geology of Rutland," p. 243.

of the altitudes of the Lower Lias under the drift shows that no such drainage could have passed northward through the Scalford valley or in either direction through the Stathern-Waltham valley. Transverse depressions or cols evidently crossed the high ground at these points before the deposition of the drift, and were possibly deepened by the passage of ice through them

In the Scalford valley, the railway-cutting at the S. end of the Long Clawson tunnel showed about 40 ft. of boulder-clay, while at its N. end only the thin edge of the drift covered the Middle Lias clays.[1]

The lower clays of the Melton brick-pits are not again actually seen in the neighbourhood, but may crop out below the stratified drift S. of Freeby and NE. of Burton Lazars. In the lower part of the Wreak valley, however, they were formerly well exposed at Rotherby and at Thrussington (*see* p. 74).

Of the Chalky Boulder Clay there are throughout the district numerous small exposures in ponds, ditches, &c., which it is unnecessary to particularize.

The sands and gravels which emerge, as previously mentioned, from beneath the Chalky Boulder Clay along the Eye valley have been described by Mr. R. M. Deeley under the name of the 'Melton Sand.'[2] They consist of yellow quartzose sand of ordinary glacial type, with beds of gravel often containing large rounded boulders and irregular thin seams of pinkish loam. They appear always to contain stones that occur also in the Chalky Boulder Clay which overlies them, and are best exposed in gravel and sand pits at Freeby, Burton Lazars, and near the mill between Melton and Kirby Bellars.

Upon and south of the Marlstone spur there is, with certain local exceptions, no marked preponderance of any particular material among the drift-boulders. Chalk and flint and Lincolnshire Limestone are on the whole the most general constituents. With these are associated Lower Lias limestone and Carboniferous sandstones and grits, widely distributed and nearly always present; Marlstone and Northampton Ironstone, abundant locally; Bunter pebbles in small quantities; and occasional boulders of Carboniferous Limestone, while fossiliferous débris of Oxford Clay may be recognized locally, *e.g.*, in the railway cutting a mile E. of Saxby Station. There occur also here and there granitic, rhyolitic, andesitic and basaltic boulders and fragments of green slate, basalt being perhaps the most conspicuous igneous rock. A boulder measuring $2\frac{1}{4}$ ft. × $1\frac{2}{3}$ ft. by the roadside at Wycomb has been described by Prof. Bonney as resembling the rhyolitic breccias of the NE. side of Charnwood Forest.[3] The finer-grained Carboniferous sandstones, more or less quartzitized and generally having a brown iron-stained crust, often preponderate in the heaps of small boulders picked off the arable land; but this is due to their durability and larger average size, and not to their relatively great abundance. Flint, also because of its durability, is nearly always in evidence; but chalk, though probably on the whole the most noticeable of the smaller rock-fragments in the boulder-clay, is in some places almost absent and yet quite plentiful in neighbouring sections. At Chadwell and E. of Scalford the boulder-clay contains so much chalk as to approximate to its condition in parts of East Anglia.

The Lincolnshire Limestone contributes largely to the boulders of the drift almost everywhere south of the Marlstone spur; and indeed from Waltham south-westward this rock, often in large angular fragments, is frequently by far the most important constituent, sometimes predominating almost to the exclusion of all other material. Further south-west, between Welby and Sysonby, large transported masses of it are imbedded in the drift, similar to those previously noticed in neighbouring districts by Prof. Morris,[4] Prof. Judd and others.[5] The largest of these masses exposed at the surface occur in the fields 800 yds. E. of the new (N.) extension of the Holwell Iron Works on a spur of boulder-clay between two valleys.[6] Their full dimensions cannot be ascertained, but they are so large that stone quarries, now abandoned and much overgrown, have been opened in them in two places, in one of which a thickness of 10 ft. or more of oolite was seen by Mr. Strangways in 1901. The rock was apparently much shattered, but was sufficiently sound to be used for road-stone.

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[1] *See* "Geology of SW. Lincolnshire, &c.," pp. 75, 78.

[2] "The Pleistocene Succession in the Trent Basin." *Quart. Journ. Geol. Soc.*, vol. xlii., 1886, p. 455.

[3] "Geology of SW. Lincolnshire, &c.," p. 77.

[4] *Quart. Journ. Geol. Soc.*, vol. ix., p. 313.

[5] "Geology of Rutland." *Mem. Geol. Surv.*, 1875, p. 246.

[6] The locality is indicated by words engraved on the geological map.

We have thus indications of a trail of débris carried in a general SW. direction from the outcrop of the limestone at Waltham, with a distinct tendency to aggregation along a definite line. Cretaceous material brought into the district from a somewhat more distant source in the north-east, is more widely distributed, yet still exhibits some degree of local concentration. On the other hand, the Carboniferous material, which may have been longer on the ground and introduced less directly, shows no such tendency to aggregation, but is scattered sparsely over the whole district. The bearing of these facts on the probable direction of ice-movement is further discussed below (p. 79).

The presence of stratified drift beneath the Chalky Boulder Clay in the Eye-Wreak valley, and of a lower boulder-clay of different composition, may indicate that the earliest glacial invasion of the district took a different direction from that which brought the later boulder-clay, and that between the two invasions there was an interval during which the fluvio-glacial material from the edge of one or both of the ice-sheets was deposited in the hollow. The general aspect of the Eye Valley east of Melton, with its ill-defined alluvial channel and its low mounds and ridges merging gradually into the flat, lends some support to the view expressed by Mr. F. W. Harmer,[1] that during one stage of the Glacial period the advance of ice up the Soar basin ponded back the drainage, so as to form a lake or swamp in the upper part of the valley.

C. B. W.

North-west of Melton the much dissected plateau of boulder-clay continues unbrokenly, save in a few of the deeper valleys, up to the high-lying S. edge of the Marlstone outcrop, upon which it thins off irregularly, but on the whole, gradually. That it hides an uneven surface of the Lower Lias is evident in several places, particularly in the neighbourhood of the Holwell Ironworks. In cuttings on the Midland Railway, S. and W. of the Works, the Lias rises to, and slightly above, the 300 ft. contour, while in a well sunk recently on the adjacent slope of Asfordby Hill, 600 yds. N. of the short tunnel on the railway, the drift was 97½ ft. thick (*see* Appendix I, p. 106), bringing down the surface of the Lias to about 250 ft. above sea-level ; and boulder-clay is also exposed at not much above this level in the excavations and sidings for the new buildings of the Holwell Works at the foot of the slope. These excavations have revealed good sections of the drift, particularly in the levelling operations at the back (E.) of the most northerly buildings, 600 yds. ENE. of Welby House, where the following section was seen in 1906 :—

	ft.
Yellowish-brown clayey soil	1
Pale yellowish boulder-clay, full of big lumps of oolitic (Lincolnshire) limestone, some large flints, a few blocks of sandstone, &c., ...	5 to 7
passing into, wedged into, and mixed with—	
Dark blue Liassic boulder-clay, with fewer stones, including some big blocks of oolitic (Lincolnshire) limestone, sandstone, &c., and plentiful crumbs of chalk ; also with wedges of gravelly loam in places	10+

The cuttings for railway sidings 100 to 200 yds. farther W. and N. also showed sections, ranging up to 10 ft. in depth, revealing 4 to 6 ft. of the yellowish oolitic and flinty boulder-clay, resting in one spot on greyish sandy loam, and in other places on dark blue Liassic boulder-clay much streaked and banded with loam ; and including near its top a reddish-purple clayey lenticle. Among the boulders in the upper clay of this section was a block of gannister-like sandstone, probably Carboniferous, 2 ft. in diameter.

These sections must reach nearly to the Lias floor, as the reservoir in the bottom of the valley was excavated mainly in Lias (*see* p. 32). The lower dark blue clay, though its matrix was Liassic, contained, in less number, the same erratics of oolite and flint as the upper clay, and the general relationship of the two types seemed to imply that they were simply modifications of the same mass due to local circumstances.

The variable composition of the boulder-clay on the deeply-trenched plateau between Asfordby and Wartnaby is evident from the numerous small exposures

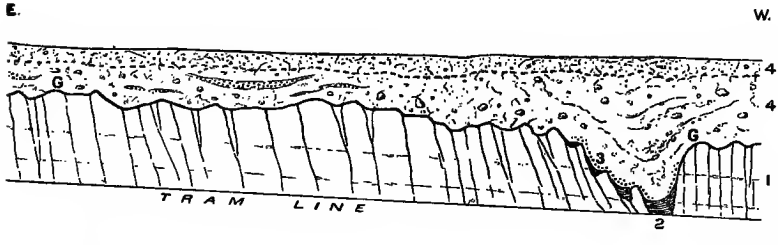
[1] *Quart. Journ. Geol. Soc.*, vol. lxiii., 1907, p. 489.

in ponds and ditches, some of which show greyish clay full of oolite, chalk and flints, while others reveal dark blue or purplish clay with much Liassic detritus and very little oolite or chalk. In a few places the occurrence of springs and boggy ground indicates the presence of permeable lenticles, probably of loamy sand or silt, at or near the base of the drift, but these are too impersistent and too indefinite to be mapped separately from the boulder-clay.

The extension of the ironstone quarries into the margin of the drift-covered ground ½ mile WNW. of Wartnaby has laid open the excellent section previously referred to (p. 48) which, at the time of writing (1908) is the best exposure in the plateau-drift. As already mentioned, the section varies in detail from time to time; its principal features are illustrated in Fig. 6 (from sketches made in the autumn of 1906 and again in 1908) and in Plates I (front.) and III.

FIG. 6.—SECTION IN SOUTH FACE OF THE IRONSTONE QUARRY AT STONEPIT HOUSES, WARTNABY, IN 1908, SHOWING 'GULL' FILLED WITH BOULDER CLAY AND REMNANTS OF UPPER LIAS. (*G. W. Lamplugh*).

Scale: 1 inch = 30 ft. horizontal and vertical.



1. Middle Lias ironstone, strongly jointed and massive, with bedding nearly obliterated: resting on 'sandrock' at the level of the tram line. The surface of the ironstone showed glacial striations at G,G.
2. Remnants of dark blue fossiliferous Upper Lias clay, let down into the bottom of the 'gull.'
3. Breccia of ironstone fragments, with stalagmite and rusty yellow clay (from Upper Lias), at base of Boulder Clay.
4. Tough dark blue Boulder Clay, largely composed of Upper, Middle, and Lower Lias débris, with occasional boulders of Carboniferous rocks, etc., and including contorted streaks and lenticles of yellow loam.

4*a*. Weathered yellow-brown stony clay, decalcified in the upper part, and with pale calcareous concretions ('race') in the lower part.

Among the many points of interest in this section, were,— (I.) The presence of a striated floor (so rare in the Midlands) beneath the drift. (II.) The composition of the boulder-clay and of its boulders. (III.) The decalcification of the boulder-clay at the surface and the concretionary segregation of its calcareous matter into 'race' in a belt below the weathered zone.

(I.) The glacial striæ occurred on several projecting knobs of the irregular floor of ironstone (p. 48) and also on the W. side of the deep 'gull' shown in Fig. 6, in the latter case running nearly horizontally on the steep face of the rock. Their direction ran between S 10°E. and S 25°E., being varied slightly by the shape of the crags That the ice-movement was toward, and not opposite to this direction was shown by the well-marked 'impact-side' and 'lee-side' of the crags, and by the drag-structures in the boulder-clay above them. It is very likely, however, that at this place local conditions have affected the ice-flow, deflecting it from its average course, which appears more usually to have been more or less to westward of south.

(II.) Though streaky and diversified with contorted wisps and oval pillow-shaped masses of earthy loam and silt which appeared to have been rolled up in the general mass, the boulder-clay was of the same type from top to bottom, except for the modification produced in the upper part by weathering. It was composed principally of Liassic

SECTION IN IRONSTONE WORKING ½ MILE WNW. OF WARTNABY (*see* Plate I).

detritus and contained many derivative fossils, the material showing that all three divisions of the Lias have contributed to the spoil.[1] Among the larger boulders were many blocks of Lias limestone; sandstones, some Jurassic (from an unrecognized source) and some Carboniferous, ranging up to 3 or 4 ft. in greatest diameter; and a few of Carboniferous Limestone, the last generally with an indurated crust, and highly polished and striated, the largest measuring 5 ft. × 3 ft. × 3 ft. The only igneous rock seen was a single rounded boulder of basalt about 1 ft. in diameter. There was a remarkable rarity or absence of oolitic limestone and of chalk or flint in the mass, but a single small piece of red chalk, containing the characteristic fossil, *Belemnites minimus*, was found in it; and a few flints were present in the surface-soil and subsoil. Yet a pond-section 40 yds. N. of the tram line at Green Hill, 1,150 yds. W. of the ironstone pit, reveals a patch of boulder-clay almost wholly made up of crushed chalk and limestone, at approximately the same elevation and forming part of the same drift-plateau; and other small sections on the plateau S. and W. of the pit also show an abundance of such material. Here again, as in the Holwell Ironworks sections, the essentially 'patchy' composition of the main sheet of boulder-clay is well exemplified.

(III.) The decalcification of the upper part of the boulder-clay in the section is interesting from an agricultural standpoint. The unweathered mass effervesces freely when acid is applied; but in the soil and subsoil, to a depth of 1½ ft. to 2 ft., either a very feeble effervescence or none at all could be detected. Below this much-weathered zone, at a depth of 2 to 4 ft. from the surface, there has been migration of the calcareous matter, and it is gathered into irregular streaks and patchy bands of pale concretionary 'race,' while the surrounding boulder clay has taken on a purplish tint, with strong and regular blue-faced jointing. Though passing gradually into the unweathered clay, the yellowish decalcified surface-layer and the stained, 'race'-mottled underlying belt are sufficiently regular in thickness to give a banded aspect to the section.

Over the bare outcrop of the Marlstone N. of the drift boundary between Wartnaby and Ab Kettleby, the rubbly soil is usually full of erratic pebbles, and the sections in the shallow ironstone workings reveal here and there gravelly 'pockets' containing many flints, quartzite pebbles, &c., with an occasional large boulder. In the pit 500 yds. W. of Ab Kettleby Lodge, among other boulders thrown out was an angular block of Carboniferous sandstone measuring 2 ft. × 1 ft. × ¾ ft. and another of andesitic rock, 15 in. × 6 in. × 4 in.

The spur of drift that juts out N. as a capping to Clawson Hill is continuous with that which fills the Scalford buried valley. Even where resting on the soft clays of the Middle and Lower Lias, N. of the fault in the solid rocks (p. 44), it does not sink much below the high level of the plateau until over ½ mile N. of the Marlstone escarpment. Then, in the next ½ mile, it descends gradually toward the plain of the Lower Lias, ending off however before actually reaching the low ground. Like the steep edge of boulder-clay forming the W. end of the plain (pp. 63–4), the features here suggest, but do not actually prove, that there has been great erosion and recession of the upland since the drifts were deposited upon it. The N. slope of Clawson Hill shows some indication that a bold slope of the Liassic rocks was in existence at this point before the drifts were deposited, but unfortunately the exposures over the whole spur are too scanty and shallow to give much information as to the composition and thickness of the boulder-clay. The projection is deeply notched by a short bifurcating valley, the branches of which descend steeply from their heads on the high ground, cutting through the drift into the Lias clays, and revealing a stratified sandy deposit which appears to be banked upon the slope between the Lias and the boulder-clay. The only clear section seen in this sand was in a small pit 60 yds. E. of Sandpit Farm, which revealed 6 ft. of red loamy sand,

[1] Among a few of the fossils that were collected and sent in to the Palaeont. Deptmt. of the Survey, the following were determined:—*Unicardium cardioides* (Phill.), *Dactylioceras* cf. *annulatum* (J. Sow.), *Harpoceras serpentinum?* (Rein.), *Hildoceras bifrons* (Brug.), *Liparoceras striatum* (Rein.), *Uptonia* cf. *jamesoni* (J. de C. Sow.), *Belemnites* cf. *acutus* Mill., and a fragment of saurian jaw.

without stones. Its prolongation up both branches of the valley and likewise on the spur between them was sufficiently indicated by the material from rabbit burrows, &c. It appears, moreover, to have been formerly dug from an overgrown pit 350 yds. SSE. of the Windmill at the mouth of the valley. The deposit lies almost entirely between the 300 ft. and 400 ft. contours, its base rising with the rise of the valley. Though not actually seen in this position, it almost certainly passes beneath the boulder-clay; but it probably thins out rapidly both eastward and westward on the outer brow of the hill, as all traces of it are soon lost, and in the obscure section at an old brickyard 350 yds. WSW. of Sandpit Farm stony clay seems to rest directly on Lias. It is interesting to note that this stratified drift agrees approximately in altitude and position with similar patches on the outer slope of the escarpment S. of Stathern, described below. They may indicate the presence of a temporary glacially-dammed lake over the Vale of Belvoir; but the evidence is at present too slight to be worth more than passing mention.

G. W. L.

The more northerly lobe of boulder-clay, between Eastwell and Stathern, as already described, breaks the Middle Lias escarpment for about a mile, and runs back SE. in a shallow depression for over 2 miles. On the surface of this tract there are practically no exposures, but the presence of the boulder-clay is indicated by the contrast of its pale clayey soil, containing numerous fragments of Lincolnshire Limestone, with the red ferruginous loamy soil of the bare Marlstone outcrop, and by the absence of the clear features of the Marlstone.

West of Eastwell the Marlstone is at the surface, but along the N. margin of the flat which it forms the drift comes on suddenly in force, for two borings within a few yards of its visible outcrop passed through 22 ft. and 30 ft., respectively, of boulder-clay without reaching the rock. At the E. end of Eastwell the village well is said to have proved over 90 ft. of boulder-clay.[1]

Further north we have no information as to the thickness of the drift. The presence of numerous blocks of Lincolnshire Limestone indicates that it descends the upper slopes of the escarpment S. of Stathern; but as the lower slopes consist of Lower Lias clays, there cannot be any deeply-cut pre-glacial through-valley between the Devon valley and Vale of Belvoir. The N. margin of the boulder-clay also ends off abruptly before reaching the ironstone workings NW. of Eaton, but is not clearly defined. A small outlier of boulder-clay, containing many fragments of Lincolnshire Limestone, forms a cap to the Upper Lias clays on Cedar Hill SSE. of Knipton at 400 ft. above O.D.

Large erratics are extremely rare over the NE. part of the map. At Harby Village there is a large block of coarse grit which may be of Carboniferous origin, and another of Carboniferous Limestone lies in a field on the SE. side of the lane 500 yds. SSW. of Stathern Church. A rounded block of hard quartzose grit and another of grey felspathic volcanic ash, each about 2 ft. in diameter, occurring in the village street at Stathern were the only other erratics of any size noticed in this district.

Pebbles of quartzite are scattered sporadically over the Marlstone plateau and also, more numerously, over the Lower Lias plain, where pebbles of other rocks are likewise not uncommon. In stripping the pebbly surface for a fresh quarry at Barnstone (p. 25), a pebble of a Silurian or Ordovician rock containing orthids was found; it may have been secondarily derived from the Bunter.

While unstratified boulder-clay is the only Glacial deposit of the higher ground in the NE. part of the map, there are some interesting patches of stratified drift occurring at lower levels. Resting in some of the recesses of the Middle Lias escarpment, and along many of the lower slopes of the deeply-cut coombes within the Marlstone plateau, as well as along the flanks of the main valley of the Devon between Knipton and Woolsthorpe, are several rather thick but discontinuous deposits of buff and red sand. Wherever found, these isolated but widely distributed deposits maintain the same general characters, being composed of a sharp, rather coarse sand, with a few flint fragments, and, very rarely, small pebbles of quartzose and other rocks in the upper layers, but without any recognizable detritus from the local rocks. The material is such as might have been derived from the coarser portions of the Lower Mottled Sandstone of the Bunter or from the Spilsby Sandstone of the Lower Cretaceous, but it could not have been obtained from any of the Liassic formations. The

[1] "Geology of SW. Lincolnshire," p. 79.

deposits contain no silty layers ; their stratification is usually obscure, and where visible conforms in most instances to the slope of the underlying surface.

In the Devon valley these sands range in altitude from about 200 ft. up to and very slightly above the 400 ft. contour ; and W. of Eastwell they run up the outer escarpment to well over the 400 ft. contour. Their relation to the boulder-clay is obscure, as they occur principally in the area where this deposit is absent ; but the patch of sand immediately SE. of Stathern, which appears to belong to the series, probably passes beneath the clay.

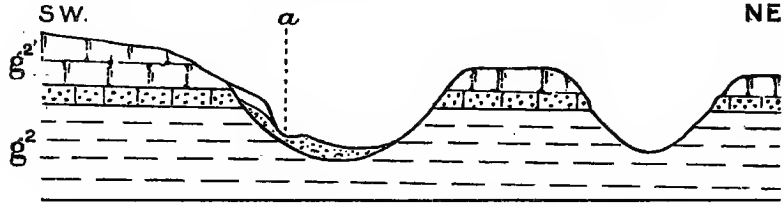
The composition and mode of occurrence of these deposits being everywhere similar, it will suffice to describe two only of the many exposures.

A small sand-hole, 200 yds. N. of the fork in the road at Combs Plantation, near Stathern, shows 7 ft. of rudely stratified sand with a few scattered flints, resting on 8 ft. of unstratified sand of which the bottom is not seen. A few yards S. of the excavation a small pond exposes over 6 ft. of boulder-clay containing numerous fragments of Lincolnshire Limestone. A belt of damp ground marks the extension of the base of the sand to within 200 yds. of Stathern Church.

A more interesting section is afforded by a sand-pit on the E. side of a by-road 330 yds. NW. of the Vicarage at Eaton, where drift-sands rest in a small valley cut through the Marlstone into the Middle Lias clays as shown in the accompanying diagram (Fig. 7), the surrounding ground being here otherwise bare of

FIG. 7.—SECTION SHOWING GLACIAL SAND IN VALLEY NE. OF EATON CHURCH (*W. Gibson*).

Hor. Scale, 6 in. = one mile. Vertical Scale, × about 6 times.



a. Sand overlain by Marlstone rubble.

g^2. Middle Lias clays. $g^{2'}$. Hard ferruginous Limestone on Sand Rock.

drift of any kind. The lower portion of the Marlstone is seen to crop out in the by-road close at hand, and also to form the abrupt slopes of the valley on both sides. The excavation is over 20 ft. in depth and fails to reach the base of the sand which evidently extends under the present floor of the small valley and rises again slightly up its opposite slope. Overlying the sand is a rubble bed, 2 to 3 ft. thick, made up of fragments of Marlstone cemented into a hard band by ferruginous and limy infiltration. This rubble gives rise to a soil very similar to that of the Marlstone itself, so that if it were not for the artificial excavation, the existence of the thick deposit of sand would not have been suspected from the surface indications, especially as the rubble-bed continues the regular slope of the valley side without change of feature. The sand is of a coarse sharp nature and contains no pebbles or admixture of local or foreign rocks. Stratification is evident and conforms roughly to the slope of the rubble-bed. No trace of shells was found either here or in any of the other places where the sands are exposed, though careful search was made.

Other excavations in these sands were observed at the following places :— Along the outer edge of the escarpment; (1) in the patch NW. of Eastwell ; (2) near the Keeper's Lodge below Terrace Hills, NE. of Stathern. In the valleys of the Devon and its tributaries ; (3) at Branston where the main road crosses the Devon ; (4) in Frog Hollow, Belvoir Castle Grounds ; (5) in Carlisle Wood, W. side of Blackberry Hill, and (6) around Knipton, but the exposures at the last mentioned place are very small and shallow.

W. G.

The SW. part of the area, including the Soar valley and that of the Wreak as far E. as Kirby Bellars, was mapped by Mr. C. Fox-Strangways along with the ground in the adjacent Sheet ("Leicester" No. 156), and a general account of its superficial deposits was included in Mr. Strangways' memoir on that sheet. The passages dealing mainly with the area lying within the present

map, are quoted below from the "Leicester" Memoir (pp. 44-48), with a few slight alterations and additions indicated by square brackets.

"The following appears to be the order of succession of these [Glacial] beds in this district :—

Valley Drift.
Great Chalky Boulder-clay with intercalated beds of sand and gravel.
Older Boulder-clay (upper part).
Quartzose Sand.
Older Boulder-clay (lower part).
Older Sand and Gravel. (?)

"*Older Sand and Gravel.*—Along the valley of the Wreak, fringing the modern alluvium of that river, there are a series of sands and gravels, the age of which is somewhat puzzling. At first sight these appear to be ordinary post-Glacial river terraces, and no doubt a good deal of the gravel along this valley is of this nature ; but at the same time there are places where the gravel appears to pass under the older Boulder-clay, and consequently must be the oldest of the superficial beds with which we have to deal.

"This appears to be the case more especially at Eye Kettleby, east of Kirby, at Rotherby, and at Rearsby, on the south side of the Wreak. On the north side the gravels at Hoby and Asfordby are probably also of this age, but the evidence is more indistinct. These beds consist of false-bedded sands and gravels, composed chiefly of quartzite pebbles and other rocks derived from the north and west, with few, if any, from the Chalk or Oolite. The sands generally contain streaks of coaly fragments, with intercalated clayey patches here and there. They rise usually from the level of the alluvium to from 30 to 40 ft. above it, flanking the meadows on either side in the ordinary manner of river terraces, so that it is very difficult to distinguish one from the other. These gravels may be of pre-Glacial age in part, and, if so, it clearly shows that the present valley is excavated nearly in the same line as the old one.

"The principal evidence for the position of these sands and gravels is chiefly in [the central] part of the Wreak valley . . . more especially at Eye Kettleby, Frisby and Hoby. . . .

"*The Older Boulder-clay.*—The principal section of this Boulder-clay is in the brickyard at Thrussington, although it is also seen along the valley to the north, and in that to the north-east of Seagrave. It consists of a stiff marly clay of a variegated red and bluish-grey colour, with small pebbles of quartzite and other rocks, but containing few, if any, large boulders, nor any derived from the Chalk or Oolite. For this reason it appears to be the result of a glaciation derived entirely from the west, and thus is in strong contrast to the Boulder-clay containing Chalk and Oolite, which has come from the opposite direction. It however contains a considerable amount of limestone derived from the Lias, which is usually well striated, as also are most of the harder rocks.

"*The Quartzose Sand.*—This name has been given by Mr. Deeley to the coarse sand lying on the Boulder-clay just described. It principally occurs along the sides of the larger valleys, and consists principally of false-bedded sand and gravel, the sand frequently containing great quantities of coal detritus.

. . . . . .

"This sand is seen resting on the Boulder-clay at Thrussington brickyard. It passes up into a laminated clay or brickearth [distinguished by a separate colour on the map] which attains its greatest thickness and best development in the valley of the Wreak at Rotherby aud to the north of Hoby.

"In the brickyard at Rotherby, where these clays were formerly worked, they are about 26 ft. thick, and pass down into a hard tough red Boulder-clay. The following is the section :—

Section in Rotherby Brickyard.

	Ft.	in.
Loamy soil, with Chalk fragments.		
Boulder-clay, containing mostly Lias fragments and quartzite pebbles, but with one or two Chalk fragments	8 0 to 12	0
Stratified clayey sand with coaly matter and a few pebbles. Thin seam of clay in upper part	4 9 to 5	0
Laminated brick-clay or sandy loam of a reddish colour, with a pebble here and there (lower part proved by boring)	... 21	0
Hard, tough, red Boulder-clay with small quartzite pebbles and a few bits of limestone, &c. (bored into)	... 12	0

"This brick-clay has a red Keuper-looking appearance, as if it had been deposited from tranquil water largely charged with the débris of that formation. It is usually underlaid and overlaid by sand, and frequently passes altogether into sand or gravel; so that the colour shown on the map denotes in some places a loamy clay, in others a sand or gravel. It appears, however, to be only on the outskirts of the area over which the brick-earth has been deposited, or among beds which occupy the same horizon—namely, between the Boulder-clay just described and the one above—that we find these coarser sands.

"The area over which the brick-clay has been deposited is about five miles across in either direction, and consequently covers about 25 square miles, of which the village of Hoby is nearly in the centre. Beyond this lenticular patches of sand and gravel occur at the same horizon throughout other portions of the district. These in many places contain a large proportion of Chalk débris, in others there is not a Chalk fragment to be found; so that, although they seem to have been deposited at about the same time, they are probably the result of conflicting currents at the period when the country was passing from the glaciation which produced the older Boulder-clay to that which formed that next to be described. Whether they are all of this date is, however, doubtful.

"These sands and gravels occasionally join on to those previously described beneath the Boulder-clay, so that without clear section it is impossible to distinguish one from the other; for this reason the colours used for Drift on the map indicate merely lithological differences without regard to their relative age.

The Older Boulder-clay (upper part).—Resting on these sands and laminated clays there is another Boulder-clay similar to that described above, in that it does not contain any fragments of Chalk or Oolite. This Boulder-clay rarely exhibits any trace of stratification, but near the base is frequently intersected by numerous striated surfaces or slickensides, which give the clay an irregular, jointed appearance. This was well shown in the section on Spinney Hills [Leicester]. . . . . .

"This Boulder-clay, which probably covers a large area, comes to the surface only on the flanks of the hills bordering the Soar and its tributaries, being nearly everywhere else hidden by newer beds, to be described presently. Its chief outcrop is along the spurs of the hills east of the Soar; but it does not appear to extend much north of Seagrave, as it is not traceable in the upper part of any of these valleys, nor was it met with in a well at the Lodge a mile north-west of Seagrave, which went through the overlying Boulder-clay directly into the Lias. Towards the east its outcrop also gradually becomes more and more obscure, so that probably in this direction it also soon thins out.

"The outcrop of this Boulder-clay frequently forms a distinct feature which is easy to recognise in walking over the ground; but, as there would be much uncertainty in attempting to trace it continuously, it has not been separated on the map from the overlying Chalky Boulder-clay.

"*The Chalky Boulder-clay.*—The Chalky Boulder-clay covers the whole of the higher ground between the numerous streams intersecting the district, except at a few places in the eastern part . . . It consists when unweathered of a darkish blue or grey clay, with fragments of chalk, flint and other rocks; but on exposure to the air it becomes decalcified and of a reddish-brown earthy nature. The amount of included fragments varies considerably in different places, sometimes there is a clay with very few stones, at others the deposit is almost entirely made up of chalk and chalk flints with very little clay. The other rocks, which include sandstones, limestones, slates, quartzites, igneous rocks, &c., from various formations, are always in a distinct minority." . . .

[In a list of Leicestershire boulders contained in the memoir from which the above passages are reprinted, a few are recorded which occur within the present map, at Burton-on-the-Wolds, Stanton, Grimston, Saxelby, Kirby Bellars and Hoby. These consist of Carboniferous limestones and grits, and Jurassic limestones; further details, which do not require repetition, will be found on reference to the list.[1]]

C. F. S.

[1] "The Geology of Leicester, etc.," p. 53.

In the neighbourhood of East Leake there are numerous large blocks of stone, including several recognizable as from the Charnwood igneous and metamorphic complex,[1] which appear to be true erratics, though they have probably been removed from their original sites. Some occur in the brook, where they may have served as stepping stones ; others in the wall of the churchyard and in other buildings ; and a few in lanes around the village. While the size, shapes and position of the boulders suggest their glacial transport, there remains a possibility that some of them may have been artificially transported from the parent outcrop for use in ancient buildings, as Charnian rocks have certainly been brought for this purpose to Barrow-upon-Soar and to Hoby and other villages in the Wreak valley. R. L. S.

The prolongation of the boulder-clay plateau northward from the Wreak valley to its broken termination in the neighbourhood of Owthorpe and Clipston is locally known as 'The Wolds.' Its surface as a whole declines gradually from an altitude of nearly 500 ft. in the SE. to 300 ft. and under in its N. and W. portions; this loss of altitude being partly due to a diminution in the average thickness of the drift, and partly to the slope of the older surface on which it rests. At the E. edge of the plateau, overlooking the Vale of Belvoir, the base of the boulder-clay usually rests upon a gently inclined surface of Lower Lias in which no sharp irregularity is perceptible, though at two or three points there are gentle undulations by which, as at Hickling Pasture for example, the Lias floor rises nearly or quite to the surface without marked interruption of the plateau-feature. Away from the edge, however, in a westerly direction, the underlying floor is more uneven, and is also generally lower.

In describing the composition and local arrangement of this portion of the drift-plateau we shall begin at the northern termination of the Wolds and proceed southward.

From Cropwell Wolds to Clipston, the matrix of the boulder-clay is a stiff clay of purplish tint. Denudation has here, for the most part, stripped the deposit from the Rhætic scarp, but near Clipston it slightly overlaps the feature and descends across the Tea-green Marls of the Keuper which form the greater part of the slope. In this quarter the matrix of the boulder-clay becomes red, like the Keuper Marls, and assumes the aspect of the red boulder-clay of the lower ground farther north.

A pond 200 yds. ENE. of Mount Pleasant, on Cropwell Wolds, shows over 2 ft. of purple clay, containing fragments of red marl, tea-green marl, black Rhætic shales, 'White Lias' limestone, Lower Lias limestone and gryphæas, and Bunter pebbles, together with a few flints and igneous erratics. Two boulders of olivine-dolerite were found in a neighbouring field, the dimensions of the larger being 18 in. × 11 in. × 8 in. Between Wolds Hill and Blackberry Hill the clay is rather sandy.

Purple clay of similar character forms the capping of Owthorpe Hill, Cotgrave Wolds and Clipston Wolds, but its Triassic contents become gradually more scanty, and its Liassic detritus more preponderant as we pass farther within the Lias outcrop. An old limestone pit at Cotgrave Wolds showed about 1 ft. of reddish boulder-clay resting upon and mingled with a slightly polished and disturbed surface of Lias limestone, on which, however, no striæ were observed.

In the belt of country stretching SW. from near Owthorpe Lodge, through Stanton Tunnel, to the neighbourhood of Widmerpool there is a gradual change in the character of the boulder-clay, so that to the SE. the purple clay with Triassic detritus is replaced by blue or greyish clay of more normal Chalky Boulder Clay type. There is, however, much patchy admixture of the two, both within the belt and on both sides of it, so that any particular section, especially if small, may differ from the prevalent type. This change is no doubt mainly due to the increasing distance from the Triassic boundary ; but it is probably accentuated by the difference which generally exists between the upper and lower portions of the boulder-clay where it attains considerable thickness. The thinner drift lying N. of the belt may therefore be equivalent mainly to the lower part of the thicker mass to the south.

The vertical change and complex structure of the thicker drift in this quarter were, indeed, clearly seen in the cuttings at the northern approach to the Stanton

[1] We are indebted to Prof. W. W. Watts, F.R.S., for their identification.

Tunnel of the Midland Railway, now grassed and obscure, but opportunely studied during the construction of the line by the present Director of the Survey, Dr. Teall, whose description of the section, written at the time but hitherto unpublished,[1] is as follows :—

"At the NW. end of the cutting near Plumtree [½ mile SSE. of Normanton-on-the-Wolds] the basal drift is composed of quartzite (Bunter) pebbles and boulders of Liassic limestone embedded in a clayey matrix of variable character. In some cases this matrix consists of pulverized black shale (masses of black shale which have been reduced to small pieces in which, however, the original lamination may be be recognised) but more frequently it is formed of red clay evidently derived from the Keuper. There is everywhere evidence of great disturbance in the basement beds which consist of masses of the local rocks broken up, jammed together and rolled over each other. The pulverised black shale is thin at the NW. end of the cutting but thickens as it is followed towards the south-east. In one or two places it is seen to have been eroded into hollows measuring 6 or 8 ft. across. Sections of two of these hollows are exposed on both sides of the cutting. They run E. and W. and are filled with sandy and pebbly drift similar to that which here caps the cutting. As the section is followed towards the SE., the disturbed black shales again decrease in thickness and are overlain by an irregularly stratified deposit of sand and clay which in its turn is succeeded by an unstratified mottled clay containing pebbles and occasional boulders of large size.

"*Section in the middle of the cutting.*

4. Red and mottled unstratified clay with large boulders—a few feet, but thickening towards the SE. so as to form a massive boulder-clay.
3. Brown sandy and pebbly drift, stratified in places and often shewing current bedding ... ... 4 ft.
2. Pulverised and pounded black shale with *Avicula contorta;* the laminæ of the separate pieces of shale are inclined at different angles ... ... 6 ft.
1. Grey shale (Keuper) *in situ* ... ... 5 ft.

"A section similar to the one just described is exposed in the Stanton cutting which leads up to the tunnel. The lowest beds are the grey marls: these are followed by the black shales more or less disturbed: and these again by the sandy and pebbly drift. The uppermost beds above the tunnel-mouth consist of unstratified boulder-clay similar to that above referred to as forming the uppermost member of the previous section. Stanton hill, through which the tunnel is being driven is mainly composed of boulder-clay which here reaches a thickness of 70 ft. Where the boulder-clay reposes on the Lias limestone, as is the case near the centre of the tunnel, the surface of the limestone is well striated and grooved, the direction of the striations being within a few degrees of NE. and SW. At the SSE. end, the tunnel is situated entirely in the drift."

In a concluding summary of his notes on these sections Dr. Teall classifies the glacial deposits into "I. The pocket-drift"—an irregular accumulation of sand and pebbles on the low ground; and "II. The hill-drift":—

"The hill-drift, as its name indicates, occurs as a capping to the hills; indeed it may be said to form the hills, for if it were removed, then between Plumtree Station and the Stanton tunnel the deepest cutting would be only 6 or 8 ft., and the tunnel would have been unnecessary. It is difficult to describe the hill-drift on account of its variability. Three principal types may be recognised. (1) Deposits formed of the local rocks (in this case, of black and grey Rhætic shales and red Keuper clays) broken up, pounded, and formed into more or less separate masses which appear to have moved over each other, as their bounding surfaces are slickensided. (2) Sandy and pebbly drift, occasionally showing stratification and false-bedding. (3) Tough unstratified boulder-clay containing here and there large striated boulders. No shell fragments were found in the stratified drifts, though they were carefully looked for."

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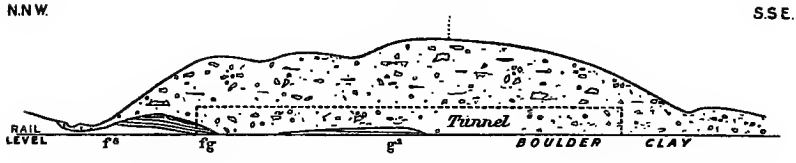
[1] A short account of this section, from information supplied by Dr. Teall and Mr. J. Shipman, is given by Mr. R. M. Deeley, in his paper "The Pleistocene Succession in the Trent Basin," *op. cit.* p. 453.

The following section (Fig. 8) through the Stanton tunnel is reduced from the original copy in Mr. James Plant's MSS.

FIG. 8.—SECTION THROUGH THE STANTON TUNNEL ON THE MIDLAND RAILWAY.

Horizontal Scale, 3 *ins.* = 1 *mile*. *Vertical Scale*, 160 *ft.* = 1 *in.*



f⁶. Tea-green Marls. fg. Rhætic Shales. g¹. Lower Lias Limestones.

The great thickness of the drift here is clearly due to the filling up of a hollow in the solid rocks, of which there is no indication whatever on the on the surface of the drift-plateau.

From Owthorpe Wolds southward, chalk is rarely, if ever, altogether absent from the boulder-clay, but it first appears in quantity S. of the road from Kinoulton to Widmerpool, where a good chalky boulder-clay sets in, sometimes containing so many flints and pieces of hard chalk that the deposit is locally known as 'gravel.' A pond-section, at the farm where the Foss Way crosses the Melton road, exposes 6 to 7 ft. of blue boulder-clay, weathering brown, which contains numerous brown flints, Bunter pebbles and pellets of chalk, besides the ubiquitous gryphaeas and other Liassic detritus. As frequently occurs in the boulder-clay of the plateau, there are sandy patches in the mass; and in these places the flints are rustily stained, causing the gravelly appearance referred to. The northern edge of this flinty drift may be traced in an almost straight line from near Kinoulton Lodge, through Flint Hill, to near Willoughby Gorse. Owing to its resistant nature, it is marked by a feature rising slighly above the more clayey portions of the deposit.

A large partly overgrown pit, about ½ mile ENE. of Curate's Gorse, showing a section 10 to 12 ft. in depth, illustrates very well the character of the drift near Hickling Standard. It consists partly of boulder-clay with a matrix chiefly of Lias clay mixed with minute fragments of chalk; but varies rapidly from stony clay to coarse reddish gravel, and to fine current-bedded flint-and-chalk gravel, and again to a whitish mass of chalk fragments.

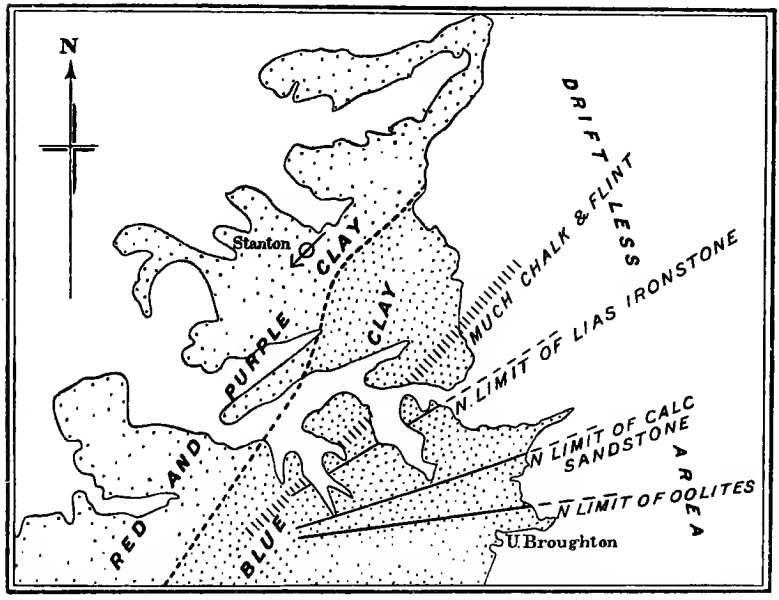
On the narrow ridge of Hickling Standard also, some old grass-grown pits disclose the presence of a somewhat sandy and gravelly boulder-clay with numerous chips of ferruginous concretions like those which occur in the Lias clays above the Ferruginous Limestone (p. 33). The distribution of these fragments in the boulder-clay appears to be limited, having its northern boundary along a line passing from Hickling Pasture to Thorpe-in-the-Glebe, and this line is also the northern limit of the clays which contain the concretions. It is noteworthy, too, that along the eastward prolongation of the same line, fragments of ferruginous limestone like that which is found in place farther eastward at Harby occur in the 'pockety' drift of the low ground around Hickling and Hose. Also, the northern limit of the transported fragments of the calcareous sandstone which is exposed *in situ* at Upper Broughton passes from N. of that place to Thorpe-in-the-Glebe; and the northern limit of the fragments of Lincolnshire Limestone is a line running WSW. from Upper Broughton.

Over the remainder of the tract between Dalby, Widmerpool and Six Hills the clay is blue and chalky, effervescing freely with acid and enclosing occasional very local patches rich in flints, sand, and chalk. The chalk is hard and often porcellanous in appearance; the flints are of all sizes and are generally brown, although among them are a few black ones; Bunter Pebbles and fragments of Lias Limestone are everywhere, and boulders of Carboniferous saudstone and limestone are present with occasional igneous rocks. In this tract too, almost all the rock-fragments mentioned above as having only a localized distribution further north are in evidence, including the Lincolnshire Limestone, Ferruginous Limestone, calcareous sandstone, and concretions.

The main facts of the distribution of the boulders are indicated in the diagram, Fig. 9. They appear to denote a direction of ice-flow in the northern part of the tract from NE. to SW., which agrees with the direction of the striæ observed on the rock-surface in the Stanton tunnel (p. 77). Farther south the movement, at any rate during the later stages of the glaciation, seems to have been more nearly E—W., though the evidence on this point is not perhaps conclusive. This change of direction and consequent convergence of the stream-lines may help to explain the complex character of the drift around Thorpe-in-the-Glebe, where patches of blue and purple clay with all the above-mentioned boulders are confusedly intermingled.

FIG. 9.—PLAN TO SHOW THE VARIATION OF THE BOULDER CLAY AND THE RANGE OF CERTAIN BOULDERS ON THE NORTH PART OF THE WOLDS. (*B. Smith*).

Scale: 1 *inch* = 2 *miles.*



Some of the boulders are occasionally found beyond the limits indicated. Outcrops of the solid rocks are unstippled.

The arrow indicates the direction of glacial striæ upon the Lower Lias limestone in Stanton tunnel.

Numerous wells have been sunk to depths of 60 to 70 ft. in the boulder-clay of the southern part of the district, and its maximum thickness is probably over 100 ft., which emphasizes the fact that the plateau is essentially built up by this clay on a westward-sloping and irregular foundation of Lias.

There are in some places obscure indications of the presence of a band of sandy loam or brick-earth at or near the base of the boulder-clay, possibly equivalent to that of the Wreak valley (pp. 74–5). Material of this kind is clearly in evidence and has been mapped at Fox Holes on Owthorpe Wolds, and at Kinoulton Gorse, but it rarely shows at the surface. Springs, however, rather frequently arise along the base-line, sculpturing the underlying Lias and producing 'scalloped' contours which contrast strongly with the more even slopes of boulder-clay above the junction, an effect particularly conspicuous under Hickling Standard and in the recesses S. of Old Dalby. The sandy brick-earth at Kinoulton Gorse was formerly dug from a large pit on the S. side of the wood; at Fox Holes, a reddish-brown sandy and stony deposit, more than 3 ft. thick, is intercalated with the boulder-clay not far from its base; and N. and S. of Clipston, sandy material of brick-earth type rests directly upon the solid rocks; while in a pond 220 yds. W. of the small spinney N. of Blackberry Hill, red clay

rests on rudely bedded sand with pebbles, the section being 5 ft. deep. There is also a larger patch of clean brick-red sand with well-rounded grains at The Trussel, on Hickling Standard. With these exceptions the portion of the plateau dealt with in the above description is singularly devoid of stratified drift of any kind.

The following is an abridged list of the most noteworthy erratics of distant origin observed on this part of the plateau; there are besides many of Liassic limestone ranging up to between 2–3 ft. in diameter which it is unnecessary to particularize :—

Carboniferous Limestone, more than 1 ft. long, ¼ mile N.W. of Wold's Farm near Upper Broughton; Crinoidal limestone, 1 ft. × 3 ft. × 18 ins., 150 yds. S. of Pasture Farm; and others of smaller dimensions near Manor Farm, Pasture Farm, and Vernometum. Boulders of brown Carboniferous sandstone, more than 1 ft. long, on Clipston Wolds. Coarse grit, 2 ft. × 1 ft. × 9 ins., at Wolds Farm, W. of U. Broughton; sandstone, 2 ft. 4 ins. × 2 ft. × 9 ins., at Longcliffe Hill, Old Dalby; and others, smaller, at Manor Farm and at points 220 yds. N. of the Fossway railway-bridge, and half a mile S. of Pasture Farm. Fossiliferous sandstones, in the brook W. of Roehoe Wood. Quartz-porphyry, 2 ft. × 2 ft. × 3 ft., E. of Clipston; olivine-dolerite, 18 ins. × 11 ins. × 8 ins., on Cropwell Wolds; flinty igneous rock (? andesitic tuff), over 1 ft. in length, Hickling Pasture; and small boulders of igneous origin near Vernometum, Stanton tunnel and other places. In addition to the above, a boulder of sandstone, 1 ft. 6 ins. × 1 ft. × 9 ins. was found at a depth of 3 ft. in the low-lying red drift, 500 yds. ESE. of The Gripps. B. S.

The NW. margin of the drift-plateau will now be described, from Clipston in the north, through Willoughby-on-the-Wolds and Wymeswold to Hoton. This tract is marked by the presence of a fringing, though interrupted, series of stratified drifts which are rare or absent in the interior of the plateau.

West of Clipston the boulder-clay is composed of Keuper material; it was proved to be more than 7 ft. thick near the NW. corner of the spur, but elsewhere may be thinner. Although boulders are now rare, we were informed locally that many have been removed in the process of cultivation. North of the village and again round the small valley S. of it, a fringe of pebbly sand emerges from beneath the boulder-clay.

The sections through the projecting spur of drift in the cuttings of the Midland Ry., near Plumtree Station, are described in the previously-quoted notes by Dr. Teall. The boulder-clay is here underlain by 4 ft. of pebbly sand.

Another spur of the high-level drift extends beyond Keyworth, terminating in a sandy mass which is probably prolonged for some distance eastward beneath the boulder-clay, as in Keyworth there are wells which derive their water from this basal stratum. A cistern in the middle of the village had passed through 2–3 ft. of soil, and 6 ft. of sharp gravelly sand when water stopped the work. Immediately E. of Keyworth the boulder-clay can be only a few feet thick, but a well for a new house a mile E. of the village, on the E. side of the road to Widmerpool, was sunk to 60 ft. entirely in boulder-clay. Another new well on rather lower ground on the W. side of the road at the same place, passed through 47 ft. of boulder-clay before reaching the Tea-green Marl which was penetrated for 9 ft. further. The water obtained in both cases is probably from the sandy base of the drift. There is no surface-feature to indicate this rapid thickening of the drift, and the proved inequalities of the solid formations are entirely obliterated. In this case the buried Rhætic escarpment evidently lies not far S. of the wells, and within this escarpment the drift becomes thinner again, as a small quarry about ¼ mile NE. of North Lodge shows only 7 ft. of brown loamy drift-clay above the Lower Lias.

An extensive area of sand with a few pebbles occurs on the plateau at Stanton-on-the-Wolds. This does not appear to be at the base of the drift, like most of the sandy beds of the district, but is probably a lenticle with a considerable thickness of boulder-clay below it.

The basal fringe of sandy drift swells out W. of North Lodge into a mass which descends and crosses the valley of the Fairham Brook. Its thickness is probably not so great as appears at first sight, as the deposit may be banked upon the corresponding slopes of an older valley. In a stream-section where the deposit crosses the brook about 15 ft. of gravelly sand is revealed, resting on 5 ft. of Tea-green Marl with red bands.

The capping of drift on Crow Hill N. of Widmerpool must be thin, as the Lias limestone has been dug in old pits at the top of the hill.

Between Widmerpool and Wysall the boulder-clay is of a reddish-brown colour, due to an admixture of Keuper and Liassic materials, and it contains also Bunter pebbles and flints. Its boundary is somewhat indefinite between Windmill Hill and Wysall; and the sandy beds mapped at intervals at its base may be continuous. At the farm ½ mile NW. of Wysall Vicarage, a well reaches water at a depth of 12 ft., which is probably the thickness of the boulder-clay here.

At Wysall the sand is no longer confined to the margin of the boulder-clay but runs due S. into the drift-plateau in a ridge broken by small streams. An old gravel-pit on the ridge ½ mile S. of Wysall showed 6 ins. of sandy soil on about 1½ ft. of gravel and coarse ferruginous sand, partly cemented and 'piped,' with the pebbles set vertically, passing down into 8 ft. or more of roughly stratified coarse sand and gravel. The pebbles, mainly very small, include some from the Bunter and others of Lias limestone with gryphaeas, sandstone (? Keuper), and chert or flint. The sand-grains are well rounded and vary greatly in size. There are streaks of coaly matter in the sand, which in this respect agrees with the "Quartzose Sand" of the Wreak valley.

In the broad tract of boulder-clay around Willoughby-on-the-Wolds, mainly pasture land, the ponds in the fields are almost the only sections. They show a stiff blue slightly stony clay, weathering brown to the depth of 1–2 ft., with patches of concretionary calcareous 'race.' The stones consist of chalk, Lias limestone, flints (usually brown and cherty-looking but occasionally black), oolitic limestone and Bunter pebbles.

As the margin of the drift is approached, W. of Thorpe-in-the-Glebe and Wymeswold, this bluish boulder-clay passes rather rapidly into a clay which is reddish-brown from admixture of Triassic material. Between Canaan Farm and Rempstone the drift is composed almost entirely of Triassic material; where Keuper waste predominates the drift is clayey, and where Bunter waste predominates it is a pebbly sand and is shown by the "sand and gravel" colour on the map. The sandy patches however often contain lenticles of red marl, so that the soil above them is frequently a loam.

Where the drift descends into the little valley of the Sheepwash Brook, ½ mile SE. of East Leake, it passes off the Lias and spreads out over the Keuper on the lower ground. This low-lying portion, however, appears to be quite thin; its boundary is for the most part difficult to trace, and it merges obscurely into the river-gravel between East Leake and Costock.

A broad stretch of high-lying sand and gravel sets in immediately S. of Sheepwash Brook, and extends uninterruptedly from Rempstone on the E., to beyond Stanford Park on the W. The sand has been excavated somewhat extensively at Rempstone. The clearest section, on the N. side of the village street 250 yds. SE. of the church, shows about 4 ft. of gravelly red clay with bits of green clay and sandy pockets, resting irregularly on 8 ft. of buff sand. The sand contains pockets and lenticles of red clay with Bunter pebbles, and a single fragment of Lias limestone was noticed.

At the cross-roads ⅛ mile WSW. of The Lings there are two sand-pits, the more southerly of which shows a clear section, consisting of 10 ft. or more of crossbedded gravel, with thick lenticles of red sand in one part of the pit only, and with carbonaceous streaks. The pebbles are mainly derived from the Bunter, but also include cherts with crinoids, rounded bits of red and of green marl and a few small boulders of Lias limestone. A well sunk recently on the N. side of the main road, ½ mile SSW. of The Lings, proved 20 ft. of red sand resting on red Keuper Marl.

In their extension westward the sands become more clayey and are apparently intercalated with boulder-clay. The deep cutting on the Great Central Railway S. of East Leake Station, when seen by Mr. Fox-Strangways[1], showed boulder-clay with sand and gravel both above and below it, resting on the Tea-green Marl; the boulder-clay contained many well-rounded pebbles of quartz and fragments of Keuper Sandstone, but very few large boulders.

The boulder-clay S. of Stanford Hills Farm makes a somewhat loamy reddish-brown or red clay soil, with Bunter pebbles.

[1] "Geology of the London Extension of the Manchester, Sheffield and Lincolnshire Railway." *Geol. Mag.*, dec. iv., vol. iv., (1897), p. 51.

The valley of Kings Brook cuts through to the solid formations as far E. as Wymeswold village, where the Lias is covered by Glacial sand and gravel which has been extensively dug. The sands pass upward into red silt which is clearly derived from the Keuper and probably from the Waterstones. These stratified deposits are lenticular, the boulder-clay of the plateau not only overlying them, but also wrapping round and under them, so that W., and perhaps also E., of the village it rests on the Lias. The elongated lenticle shown on the map between Wymeswold and Hoton is composed of pebbly sand.

South of Wymeswold the boulder-clay is of the chalky type, but W. of the road to Burton-on-the-Wolds it begins to show an admixture of Triassic material; near Gorse Spinney it is of mixed Triassic and Liassic composition; and a little farther W. the Triassic detritus predominates so that it becomes a red more or less loamy clay, with Bunter pebbles. At Hoton the soil of the boulder-clay is very like that of the Keuper Marl, but the admixture of Bunter pebbles and sand with the drift enables them to be distinguished. The clayey drift of the Hoton Hills is of the same character.

In the patch of stratified drift near Hoton Hills farm, a pit shows 6 ft. of gravel resting on about 11 ft. of whitish sand without pebbles, but containing coaly streaks. This sand is dislocated by small reversed faults, which are brought out very conspicuously by the presence of the black streaks.

The Keuper Lowland.—Leaving the plateau and descending to the lowland occupying the NW. corner of the map, we find a striking difference both in the amount and in the composition of the Glacial deposits. Indeed the conditions are here analogous to those in the Vale of Belvoir, except that the gravelly patches are often sufficiently thick and continuous to require representation on the map.

There is the same presence of wide tracts in which the solid formation—in this case, the Keuper Marl—lies close to the surface, though still with sufficient sandy and stony detritus in the soil and subsoil to modify their agricultural character; and the same absence of any deposit which can be confidently classed as boulder-clay. Even the small patches on the W. margin of the map, S. of Clifton, and on its N. margin NE. of Clipston, shown with the Boulder Clay colour on the map are very different from the strong 'till' of the plateau. They consist of a mixture of red clay, sand, and Bunter pebbles in almost equal proportion and are hardly distinguishable from the more clayey parts of the Sand and Gravel series, into which indeed the supposed Boulder Clay makes an imperceptible passage in the neighbourhood of Clifton Pasture.

The smaller patches of sand and gravel shown in the NW. part of the map, in nearly every case occur as protective cappings to more or less prominent hills. Between Glapton, Bradmore and Plumtree, these gravel-capped hills are arranged roughly *en échelon* along a W–E. line with their longer axes in a general NW–SE. direction. This probably reflects in some degree an original disposition of the gravels, for although their area has evidently been much reduced by erosion, the patches which remain probably represent the places where they were at first thickest.

It is only in a few cases that there are sections in the gravelly patches, and one frequently has to be satisfied with the indications afforded by the soil, &c. The best section seen in them was a temporary one in an excavation for a reservoir on the top of Wilford Hill, at the N. edge of the map, at 280 ft. above O.D.,[1] which was carried to a depth of about 9½ ft. in a confused and contorted mass of gravelly sand and clay, with obscure and partly obliterated bedding. The pebbles examined were all such as might be derived from the Bunter; and were generally arranged with their longer axes vertical.

The large patch of sand and gravel around Ruddington Fields, at about 120 ft. above OD., is cut through by the Great Central Railway; the section is now obscured, but from observations made when it was fresh by Mr. C. Fox-Strangways, and by the late J. Shipman, we learn that the middle of the cutting showed about 17 ft. of sand and gravel with pipes of red clay, resting on a contorted surface of red Keuper Marl; while 30 yds. S. of the footbridge opposite Ruddington Fields Farm, it revealed only a little sand, overlying 10 ft. of red clay with pebbles and flints, resting on Keuper Marl.

Blackcliffe Hill, between Bradmore and Plumtree, although similar in outline to the slightly lower neighbouring hills which are gravel-capped, and although it

[1] We are informed by Mr. F. W. Davies, Water Engineer to the Nottingham Corporation, that the original surface-level at the centre of the reservoir was about 284 ft. O.D.

has sandy pebbly soil on its flanks, has red clay, presumably Keuper, at its summit, and no gravel. A boulder-like block of white sandstone, (Carboniferous?) measuring 2½ × 1¼ × 1 ft. was seen at the roadside on the NE. slope of the hill.

At Bradmore the gravels cap the rise on which the village stands (165 ft. above O.D.). A slightly lower ridge of similar material occurs about ⅓ mile SE. of the village, and falls southward into the thin terrace-like sheet of pebbly sand which covers the lower ground of Bunny Park. The rising ground at the eastern margin of the Park, on both sides of the Fairham Brook, has also a gravelly covering, in which the presence of a few flints, in addition to the usual Bunter pebbles, is noteworthy.

During the construction of the G. C. Ry. the wide flat of peaty alluvium stretching from Gotham to Bunny was seen by Mr. Fox-Strangways to be underlain for the most part by sand and gravel, which is probable the continuation of that of Bunny Park. A boulder of flinty ash, 2 ft. long, probably from the Lake District, and another 1 ft. long which may be of Buttermere granophyre, were noticed on the bank of a drain at the SE. side of Clifton Pasture, having apparently been dug out from the drift below the alluvium.

The patch of sandy drift ½ mile NW. of Plumtree, at about 150 ft. above O.D., has been worked in an old pit, about 10 ft. deep, which shows sand with Bunter pebbles overlying the Keuper Marl. The smaller patch, which is cut by the railway at Plumtree Station, attains an elevation of a little over 200 ft. above O.D., and consists of an irregular accumulation of sand and pebbles, extending downwards in 'pockets' for a few feet into the disturbed surface of the Keuper.[1]

The two small tracts of sand and gravel lying within the East Leake valley are of similar character to those above described; the deposits in both cases occur near the 200 ft. contour, and rest on Tea-green Marl; the more westerly patch seems to be quite thin while the other is of rather more consequence.

R. L. S.

The Vale of Belvoir.—We have already incidentally referred to the singularly scanty traces of glaciation over the whole of the low ground N. of the Marlstone escarpment and E. of the sharply defined edge of the boulder-clay plateau. Later denudation has no doubt assisted to bring about this result, but the facts seem to imply that for some reason, as yet unexplained, there was never any deposit of drift in this tract comparable in magnitude to that of the neighbouring uplands (p. 64). In no part of this Liassic plain is there any deposit which can be definitely mapped as Boulder Clay. Bunter pebbles, chalk-flints and occasional far-travelled boulders are however scattered sporadically all over the Vale of Belvoir, and here and there are concentrated sufficiently to form patches of gravelly drift let down in irregular 'pipes' and 'pockets' into the ragged surface of the Lower Lias. This material is too impersistent and too much entangled with the subjacent clays to be worth showing in colour on the map; but the areas in which it is most abundant have been thereon indicated by an engraved boundary-line and by descriptive words. Where the gravelly and sandy 'pockets' are deepest and most numerous, they have some effect in modified the generally very stiff character of the clay-soils of the Lower Lias, but they appear to be nowhere sufficiently thick or persistent to be worth working for gravel. Their mode of occurrence can be best studied in the excavations of the Barnstone Cement Works, at the N. margin of the map, which have been described in a previous memoir.[2]

G. W. L.

A pond 330 yds. NW. of Langar Lodge showed a similar section to those at Barnstone, pebbly material being looped in pockets, 4 or 5 ft. deep, into the disturbed surface of the Lias. The patchy nature of the deposit was well seen, also, in a field 2,000 yds. SW. of Langar Church, the eastern half possessing a stiff clay soil, while in the western part an excavation showed the following section:—

	ft.	in.
Sandy soil	1	0
Gravel of rounded and subangular sandstones, flints, cherts, &c., mixed with sandy clay	1	0
Sand	1	6

[1] From notes by Dr. Teall on these cuttings; see *ante*, p. 77.

[2] "The Geology of the Country between Newark and Nottingham" (1908), p. 72.

In the SW. part of the plain the banks of the stream which flows past Hickling show, N. of the village, an almost continuous section in a pockety deposit of gravel about 1 ft. thick, containing many fragments of ironstone. The gravel is covered by a varying thickness of loam, but it is not itself fluviatile as it occurs in pond-sections outside the alluvial tract.

Most of the larger erratics of the Vale of Belvoir are now placed at road corners in the villages. In Hickling, 7 or 8 boulders of coarse sandstone and grit were noticed, the largest measuring 3 × 3 × 2 ft.; large blocks of limestone may be seen at Kinoulton; several grits at Owthorpe; and at Old Dalby there is a mass of coarse grit, in a field near the school, measuring 2 × 3 × 1 ft., and a boulder of dolerite with hexagonal jointing, 2½ ft. in length, in a garden near the inn. B. S.

Older River Gravel (Late Glacial Flood Deposits).

After the deposition of the Chalky Boulder Clay and the high-level Glacial Gravels associated with it, there followed a time of severe and probably very rapid erosion. During this stage deep valleys were excavated in the drift-plateau, often trenching also into the underlying formations; and in some districts almost the whole of the drift was removed.

From the occurrence of the remains of extinct mammalia in some of the valley-deposits, and from the character of the deposits themselves, it is evident that the major portion of the work of erosion dates back to a time when the conditions were very different from those which now prevail, even the subsidiary drainage channels being then subject to floods of great power. These conditions probably accompanied and immediately followed the closing stages of the local glaciation; in which case the older of the valley-deposits should be classed as of Late Glacial age, since their accumulation is likely to have been contemporaneous with the actual glaciation of other districts which remained longer under the influence of the ice. It has indeed been suggested that deposits of similar character in the neighbouring parts of the Trent basin may indicate an Interglacial period,[1] but we have found no evidence favourable to this supposition.[2] G.W.L.

These older valley-deposits are therefore separated on the map from the more recent River Gravel and Alluvium, by a distinctive symbol. They occur principally in the valley of the Wreak and along the eastern edge of the Soar valley, in ground surveyed by Mr. C. Fox-Strangways, who referred to them in the 'Leicester' memoir in the following terms[3]:—

"There is also possibly a third series of clays and gravels which were laid down at a much later date [than the Chalky Boulder Clay], after the existing valleys had been cut out, and consequently it is only found at the lower levels. This is so intimately connected with the post-Glacial river beds that probably it

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[1] R. M. Deeley. "The Pleistocene Succession in the Trent Basin." *Quart. Journ. Geol. Soc.* xlii, 1886, pp. 467 *et seq.*

[2] For fuller discussion of this subject, *see* "The Geology of the Country between Newark and Nottingham." *Mem. Geol. Surv.*, 1908, pp. 73–4.

[3] *op. cit.* pp. 43–4, 55–6.

should be included with them. It may represent a passage from one state of conditions to the other."

. . . . . .

"Along the valleys of the Soar and Wreak there are well-marked terraces of river gravel flanking the modern alluvium of these rivers. These are about 20 ft. above the present river flat," [on the average, but rising to over 35 ft. above the flat of the Wreak between Hoby and Thrussington and again between Asfordby and Hoby]; "and near the confluence of the two rivers at Syston [in Sheet 156], form considerable spreads of flat gravelly soil. They have evidently been deposited when the rivers flowed at a higher level, and when there was a greater volume of water than at the present time. These terraces in many places extend up the lateral valleys, and in their upper part join on to the alluvium of those streams so that it is difficult to separate one from the other."

C. F. S.

An irregular deposit of stony clay, mixed with contorted gravelly patches, which lines the floors of some of the smaller valleys of the district is described by Mr. Fox-Strangways under the term "Valley Drift."

"[It is so named] from its occurring along the lower ground, and in the bottoms of valleys which have been denuded since the older glacial beds were formed. This drift occurs along the small tributary valleys about Barrow and Sileby, and seems to be occasionally present beneath the river gravels, but no clear sections have been seen in this area. It is never of any great thickness, usually not more than about five feet or so, and appears to be largely made up of pre-existing boulder-clays. It contains irregular lenticular patches of sand and gravel, which appear to have been thrust into the mass of the clay; but the most noteworthy fact in connection with this glaciation is that the upper portion of the Lias strata, on which it reposes, is nearly always more or less disturbed, and frequently violently contorted, with patches of gravel thrust into it for some depth. A good section of this was shown in the limestone quarry about a mile NE. of Barrow Church [a diagram of which is given in the 'Leicester' memoir, Fig. 14]"

The clayey Valley Drift above described merges into the higher terraces of the Soar at the mouths of the tributary valleys. It seemed to the present writer who re-examined the sections, that the material is mainly the result of 'creep' and down-wash from the clayey slopes of the valleys, mingled and contorted with the old gravelly sediments of the streams. The best exposures of it are in the banks of the Fishpool Brook and of the small stream running SW. from Seagrave. In many respects it resembles the 'patchy drift' of the Vale of Belvoir (p. 83). The ancient flood-gravel of Bunny Park, previously described (p. 83) seems to be of about the same age. The transition from the earlier to the later (Recent) valley-deposits was, however, so gradual that it is more or less impracticable exactly to correlate the different stages in areas that are not contiguous.

The bones of mammals found from time to time in the superficial deposits of the Soar and Wreak valleys include some extinct Pleistocene species which are probably from the Older Gravels, through the records are rarely definite on this point. A tooth of the mammoth (*Elephas primigenius* Blum.) from Kirby Park, Melton Mowbray (probably from the terrace-gravel there), was preserved in the Woodwardian Museum, Cambridge, and has been figured by Dr. Leith Adams.[1] It is stated by Mr. Jas. Plant[2] that the entire skeleton of an elephant (*Elephas antiquus* Falc.) was unearthed many years ago in a quarry at Barrow-upon-Soar, but crumbled on exposure so that only portions of the tusks, teeth and some fragmentary bones could be preserved. From the description it appears likely that these remains occurred in the patch of the Older Gravel upon which the town partly stands. G. W. L.

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[1] "The British Fossil Elephants" Part ii., Pl. xiii. *Mon. Palæontol. Soc.*, vol. xxxiii., 1879.

[2] "Notice of the Occurrence of Mammalian Remains in the Valley of the Soar, Leicestershire." *The Geologist* vol. i., 1859, p. 174; and *Trans. Leicest. Lit. and Phil. Soc.* 1858, pp. 20–21.

CHAPTER IX.

POST-GLACIAL RIVER GRAVEL AND ALLUVIUM.[1]

River Gravel.

Below the level of the Older Gravel discussed in the preceding chapter, the valley of the Soar is fringed by terraces of gravel and loam of later date which carry on the history of the river to the Recent stage when the alluvium of its present low-level flat was deposited. As already mentioned, there is often no sharp distinction to be drawn between the older and the later gravels, so that their classification on the map is necessarily somewhat arbitrary; but, in a broad way, the later gravels are equivalent in position, structure and origin to the Trent Gravels of the Trent valley, described recently in a memoir on the adjacent map. (Sheet 126: "The Geology of . . Newark and Nottingham," 1908, pp. 77–80.) In the neighbourhood of Woodthorpe the gravels range up to 8 ft. in thickness; at Loughborough along the line of the Gt. Central Ry. they were proved to a depth of 10 ft. or more and pass beneath the Recent muddy alluvium of the river[2]; and east of the Soar they form a thin and patchy veneering on the somewhat indefinite and broken terraces between Stanford and Barrow.

The Wreak valley below Asfordby has similar gravels, which are however more or less inseparable from the Older Gravel on the sides of the valley, and are buried under the Recent clayey alluvium on its floor.

The Fairham Brook has thrown out a delta of sand and gravel where it emerges from its narrow valley to the Keuper flat at Bunny. The recent flat of the stream has been sunk along the southern side of this delta. G. W. L.

Alluvium.

The alluvial flats of the Wreak and Soar, as above indicated, are mainly composed of loamy and clayey deposits, overlying gravels brought down when the streams were more powerful than they now are. Under present conditions, the volume of the streams is sufficient to clear away only a portion of the clayey matter brought down into their valleys by the numerous small but active tributaries decending from the boulder-clay plateau. Consequently little or no deepening of these main valleys appears to have taken place in recent times. On the contrary, there has been a tendency toward the piling up of alluvium on their floors.

This slackening of the main drainage has produced a corresponding effect in the lower parts of the tributary valleys, in which the alluvial flats are generally disproportionate to the present size of the streams.

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[1] By the authors of the memoir whose initials are appended to the text.

[2] For details of sections *see* "Geology of . . . Derby, &c., and Loughborough" (Sheet 141). *Mem. Geol. Surv.* 1905, p. 58.

The flats bordering small streams on the Lower Lias clays and on the Keuper Marl are often unusually wide, with ill-defined outer margins; but it is doubtful whether these flats have been wholly planed down by the streams, as would at first sight be supposed. In many cases it is probable that they have been enlarged by the general lowering of the surface occupied by exceptionally 'weak' strata, under ordinary atmospheric weathering. In such instances where the drainage is arrested, the original valley-floor is more or less protected by its covering of alluvium, while the bounding slopes of 'weak' material may be gradually lowered to the level of the flat. On low ground it was frequently observed that where the stream-flat was widely extended, the actual deposits of alluvium were confined to a comparatively narrow strip along the course of the stream, as would happen under the above conditions. The broad tract of shallow alluvium in the NW. part of the map, between Clifton Pasture and Bunny, appears to be due to a similar process. G. W. L.

An interesting section of ancient alluvium is exposed in Barnes's brickyard on the northern outskirts of Melton Mowbray, at the confluence of a side-valley with the broad valley of the Eye. At a depth of about 9 feet, beneath loamy brick-earth, there occurs a tough blue clay, of which the sandy base contains boles and roots of trees, with bark and hazel-nuts. This bed rests upon a thin irregular band of coarse gravel, containing many flints derived from the Chalky Boulder Clay; and in this gravel are occasionally found well-preserved mammalian bones. These remains include a human cranium, the skull of a horse, and bones and antlers of red deer. The gravel rests upon purple and grey clay, equivalent to the lower boulder-clay of the adjacent pit (p. 67), the Chalky Boulder Clay having been removed by erosion before the gravel was deposited.

C. B. W.

DETAILS.

Where the Fairham Brook debouches from its narrow and well defined valley at Bunny, it enters a wide flat covering nearly 4 sq. miles, which was evidently bog-land until artificially drained. The different parts of this tract are known as Bunny, Bradmore, Gotham, Barton and Ruddington Moors; it is covered for the most part by black peaty soil usually only a foot or so in thickness, which in the S. and W. parts of the flat rests on red clay (re-deposited Keuper), but elsewhere generally on a thin irregular bed of sand and small gravel containing many fragments of flint and same gryphaeas. The outcrop of a gypsiferous belt in the Keuper Marl falls partly within this tract, which is therefore analogous to the flats along the Rivers Smite and Devon in Sheet 126, similarly underlain by gypsiferous strata.[1] The occurrence of the flats in this position suggests that they may be due to the solution of the gypsum veins, and consequent disintegration of the associated Keuper Marl. Another but much smaller expansion of the alluvium connected with Fairham Brook takes place at the inflow of two small tributaries NW. of Ruddington, where again a peaty flat is developed.

The two small patches of stream-alluvium E. and SE. of Edwalton consist of dark peaty clay resting on whitish clay. In the park of Rocklaveston Manor, the Thurlbeck Dyke emerges from a narrow valley on to a flat covered with dark peaty clay containing numerous land and freshwater shells (for list *see* memoir[1] on Sheet 126).

[1] "Geology of the Country between Newark and Nottingham." *Mem. Geol. Surv.*, 1908, p. 89.
[2] *Ibid.*, p. 88.

The stream which flows through East Leake has a narrow but well-marked alluvial flat in its upper reaches, which contracts where it crosses the limestones at the base of the Lias, but expands again on entering the Keuper outcrop at Costock. From Costock westward to the margin of the map, the alluvium is bordered on the south by a low terrace of river gravel. R. L. S.

The alluvium of the small streams draining the Vale of Belvoir is usually a brown stony loam derived from the weathered Liassic clays with an admixture of pebbles from the drift. This loam which rarely exceeds 2 or 3 feet in thickness has generally a thin gravelly layer at the base. Most of the streams of the district have been artificially controlled and straightened in one part or another of their courses.

Near the junction of the Smite with its W. tributaries S. of Colston Basset, and near the Devil's Elbow, the alluvium consists of 1 to 2 ft. of brown clayey loam with interspersed pebbles, often resting upon patches or streaks of pebbly and flinty gravel. Similarly the broad expansions of brown loam between Hose and Hose Gorse contain occasional stones, sandy and gravelly streaks, and fresh-water shells. The prevalence of gravel in and under the alluvium suggests that the 'pockety' drift of the Vale of Belvoir (p. 83) has been much reduced by denudation.

The alluvium E. of Blue Hill consists of variegated green, brown and red loams, derived from the Trias, with occasional streaks of whitish shelly marl and clay at the bottom. There is a general absence of peaty soils over the Liassic portion of the Vale of Belvoir. B. S.

CHAPTER X.

ECONOMIC GEOLOGY.[1]

Mineral Products; Building Materials; Water Supply; Agriculture, &c.

COAL.

The extension of the Nottinghamshire Coal-field beneath the newer rocks in the northern part of the map has been discussed in Chap. II. of this memoir. Operations are at present in progress which are intended to test the commercial value of this area.

The chief mineral products worked in the district are the ironstones of the Middle Lias, the cement-stones of the Lower Lias, and the gypsum of the Keuper Marl.

MIDDLE LIAS IRONSTONES.[2]

General Account.—The winning of the Middle Lias ironstone forms an important industry. The modern introduction of the ore in 1873 by Mr. R. Dagliesh was the revival of an ancient local industry. It has led to a rapid development of the field, so that in recent years the district has supplied large quantities of ore not only to the local furnaces of the Holwell Ironworks but also to distant ones in the Erewash and Rother valleys.

The chief Liassic ironstones of England occur at two horizons. The lower, represented by the ironstones of Frodingham in Lincolnshire, occurs in the Zone of *Arnioceras semicostatum* of the Lower Lias; but as previously stated (p. 24) the ferruginous beds of this zone die out near Harby and nowhere produce a marketable ore within the present district. The second ironstone horizon belongs to the Zone of *Paltopleuroceras spinatum* of the Middle Lias. This includes the well-known Cleveland ironstone of Yorkshire and the chief ore of Leicestershire. In the Midland Counties, this ferruginous horizon of the Middle Lias sets in near Market Harborough in Rutlandshire and dies out near Leadenham in Lincolnshire, reaching its maximum development within the limits of the present map. The ore body here lies between the Upper Lias clays above and the Marlstone Sandrock (p. 40) below. Between these limits the profitable ore averages 10 ft. in thickness, but over large areas the thickness rarely exceeds 7 ft., while 14 ft. may be taken as a maximum.

The ironstone varies in character according to the degree of concentration and weathering, from a soft earthy variety containing very little lime to a hard ferruginous limestone, with intermediate types in which the concentration and weathering has been partly accomplished. In the soft stone the body of the ore has a deep yellow or light mahogany-brown colour. Along joints, cracks and bedding planes the iron-salts have been concentrated in veins of a deep red colour, up to ¼ inch in thickness, producing a general concretionary and cellular appearance. Thin films of black oxides of iron frequently coat the joint faces and usually indicate the richest

[1] By all the authors of the Memoir.
[2] By W. Gibson, with notes by C. B. Wedd & G. W. Lamplugh.

parts of the stone. Oolitic grains are obvious to the naked eye. Kernels and occasionally thin beds of bluish-grey or greenish worthless stone (termed 'jacks' by the miner) occur in the body of the ore. Under the microscope these are found to consist of organic fragments set in a matrix of colourless crystalline limestone.[1] The green portions are probably coloured by silicate of iron since in these green varieties there is not a sufficient amount of phosphoric acid to produce any effect on the tint.[2]

Harder stone of the intermediate type occurs at Wartnaby and to the south-east of Eastwell. At the former locality the stone lies under Boulder Clay and at the latter under the clays of the Upper Lias. The ferruginous limestone type prevails in the proximity of the Upper Lias outcrop between Eastwell and Knipton, but it is only worked as an ore at Harston (Sheet 143) in the Belvoir district.

As regards the origin of the ironstone, we can apply the explanation which has been given for the similar Middle Lias ironstone of the Cleveland district. It has been shown by the late Dr. H. C. Sorby that this rock has been formed by the alteration of an ordinary limestone through the percolation of water containing carbonate of iron in solution. The same observer has experimentally shown[3] that the alteration can take place at ordinary temperatures, though the process is appreciably slower than in heated solutions. The first step in the alteration of the original limestone is the replacement of the calcite by ferrous carbonate. This is followed by the oxidation of the latter and the formation of brown hæmatite. At this stage a general diminution of the strata takes place amounting to as much as 12 per cent., and results in the formation of open joints and increased porosity of the strata, factors of considerable influence on the final redistribution and concentration of the iron salts.

The manner in which the concentration takes place is thus described by Prof. Judd.[4]

"Now, as the water containing oxygen penetrates into the substance of the rock from a joint or bedding plane, its first effect would be to part with its oxygen and to take up a quantity of carbonic acid; but carbonate of iron being very soluble in water containing carbonic acid, the liquid contained in the inner portion of the rock would soon become strongly chalybeate; this liquid, passing outwards by diffusion, would meet fresh water entering containing free oxygen, and at the place where the two liquids came into contact we should instantly have a precipitation of hydrated peroxide of iron. This deposition of insoluble material would of course be liable to take place in planes roughly parallel to those from which the water acted, and when once such a barrier as this was commenced in the midst of the rock, to however slight a degree, it would constantly tend to increase, by retarding alike the outward passage of the chalybeate water and the inward passage of the oxygenated water."

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[1] J. J. H. Teall, in "The Jurassic Rocks of Britain," vol. iv. 1894, Pl. II. and p. 28. *Mem. Geol. Surv.*

[2] H. B. Woodward, "The Jurassic Rocks of Britain," vol. iii., 1893, p. 301. *Mem. Geol. Survey.*

[3] "Naturalist," 1906, p. 354–7.

[4] "The Geology of Rutland, &c." *Mem. Geol. Surv.*, 1875, p. 135-6.

The method adopted in working the ironstone is that technically known as open-cast. A trench is first cut in a straight line and the stone is then removed along either one or both faces. The soil, subsoil and any unprofitable material is strewn over the surface laid bare by the removal of the ore and crops are almost immediately planted on this new soil, so that there shall be as little interference as possible with the agriculture. The ore is generally sent to the furnaces in a raw state, but it is occasionally calcined on the spot.

The average composition of the different grades of ore is shown in the following analyses.[1] Though of low grade, like most Mesozoic ironstones, this is counterbalanced by the cheapness with which it is won. In the richer ores the metallic iron rarely exceeds 40 per cent. of the rock and in the limy stone of the Harston area it falls below 30 per cent. W. G.

The following are analyses of Marlstone iron-ores in the Woolsthorpe and Belvoir districts :—

	I. Woolsthorpe.	II. Belvoir.	III. Belvoir.
	All dried at 212° F.		
Peroxide of Iron	57·86	56·25	32·03
Protoxide of Iron	—	—	5·82
Protoxide of Manganese	0·15	0·22	0·28
Alumina	12·80	10·07	7·56
Lime	3·47 (2)	1·05	17·56
Magnesia		0·32	0·63
Silica	11·80	12·76	11·75
Sulphur	0·04	0·02 (3)	0·02 (3)
Phosphoric acid	0·90	0·40	0·41
Combined water [with CO_2 in II. and III.] ...	12·78	18·2	22·22
	99·80	99·29	99·28
Metallic Iron	40·50	39·4	26·9

Analyses of the undried ore from the Eastwell and Holwell districts are given in the following table :—

	IV. Eastwell.	V. Eastwell.	VI. Holwell.
Protoxide of Manganese	0·21	0·183	0·45
Alumina	8·30	6·50	8·37
Lime	2·20	10·50	1·17
Magnesia	0·87	0·352	1·08
Silica	10·48	9·44	10·04
Sulphur	0·02	0·053	0·03
Phosphoric acid	0·71	0·432	0·57
Loss on calcination	13·66	21·02	12·18 (4)
Moisture	21·92	16·64	19·02
Metallic Iron (raw)	29·38	23·92	32·87
Metallic Iron (dried at 212° F.)	37·63	28·70	40·60

[1] For Nos. II, III, VII, VIII & IX, of these analyses we are indebted to Mr. W. Fowler of the Stanton Coal & Iron Company, and for Nos. IV & V, to Mr. H. Westlake of the Staveley Coal & Iron Co. Nos I & VI, are reprinted from "Geology of SW. Lincolnshire, &c.", p. 120, No. VI being originally supplied by Mr. R. Dalgliesh. Other analyses will be found in the memoir cited and in "Jurassic Rocks of Britain," vol. iii., pp. 305–6.

(2) As carbonates. (3) Sulphuric acid.

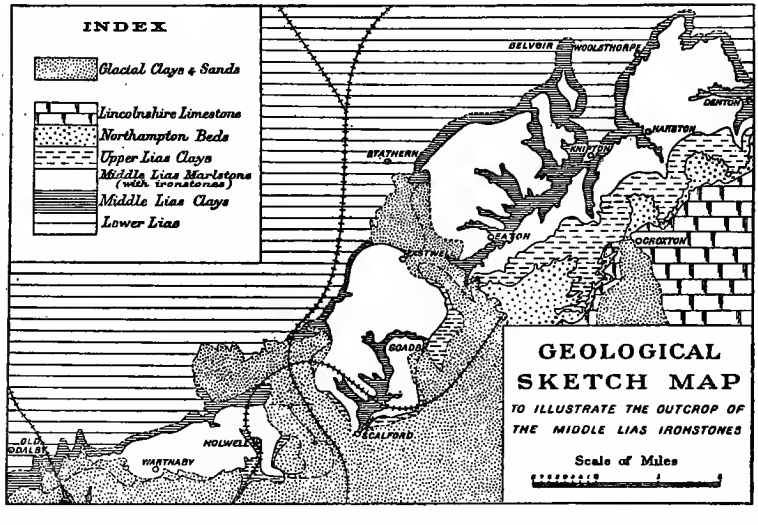
(4) Combined water and CO_2

The differences between the composition of the two varieties of ore are further illustrated by the following analyses from the Holwell and Wartnaby districts :—

	VII. Holwell Hard ore.	VIII. Wartnaby Soft ore.	IX. Wartnaby Hard ore.
	All dried at 212° F.		
Peroxide of Iron	35·6	60·736	48·24
Protoxide of Iron	4·23	Nil.	Nil.
Protoxide of Manganese	·166	Trace.	Nil.
Alumina	13·86	8·484	8·81
Lime	14·488	·886	10·708
Magnesia	1·086	·463	·934
Silica	11·68	14·42	12·27
Phosphoric acid	·326	·63	·203
Combined water and CO_2	18·0	14·474	18·45
	99·436	100·093	99·615
Metallic Iron	28·2	42·315	33·75

Details of the workings.—The principal sites of the ironstone workings are indicated by an engraved stippling on the one-inch map. They have extended more or less continuous along the outcrop of the Marlstone from Wartnaby on the SW. to the Terrace Hills near Belvoir on the NE., and in some parts of this tract the ore is now nearly exhausted. There are also somewhat extensive workings at Woolsthorpe and Denton, slightly beyond the NE. margin of the map.

FIG. 10.



The outcrop of the Marlstone is shown in the above sketch-map, Fig. 10, which has been extended beyond the E. limits of the one-inch sheet in order that it may include the Woolsthorpe and Denton sites. It will of course be understood that the area of Marlstone herein shown covers the tracts from which the ironstone has already been removed and those where the ore may be too thin or too inferior in quality to be economically valuable; and it also covers the outcrop of the worthless sandrock beneath the ironstone.

At the NE. extremity of the tract shown in Fig. 10, are the Woolsthorpe workings of the Stanton Coal and Iron Co. which fall into two groups, separated

by the road from Harston to Denton. The workings north of the road extend E. from the crest of the wooded Marlstone escarpment between Woolsthorpe and Harston to the branch line of the G. N. Ry. north of Denton. They are in the soft thoroughly decalcified ore in which areas of poor stone are rare. With the exception of two trifling faults, having a general E–W. course, in the S.W. part of the workings, the ironstone beds are practically undisturbed. The thickness of the ore varies between 6 and 10 ft. Narrow channels, filled with sand and rubble are occasionally encountered, but these rarely cut out the entire thickness of the stone.[1]

In the workings south of the Denton road the ore is a hard compact rock, best described as a ferruginous limestone, which constitutes an ore that is of low grade, but cheaply got and locally free from deleterious ingredients. It is sent out of the district to be smelted in conjunction with the rich Black Band ironstones of N. Staffordshire.

Beds of apparently similar character crop out beneath the Upper Lias on the E. side of the Devon ; but they have not yet been put to the commercial test.

On the dip slope of the escarpment E. of Stathern the Staveley Coal & Iron Co. and the Holwell Iron Co. possess extensive workings which extend E. toward the Devon Valley. In these, the ore is of the soft mahogany-brown variety, and has a thickness increasing from 1 ft. near the escarpment to 12 ft. in the main workings on the dip slope. The cover, consisting of soil and rubble, varies from 3 to 9 ft. W. G.

The workings of the Staveley Coal and Iron Co. extend around Eastwell and thence SE., right across the outcrop, to White Lodge near Goadby Marwood where the stone is followed for a little distance beneath the Upper Lias clay and overlying drift. Here again the ore is of the soft earthy type where it occurs on the bare plateau, but becomes harder and more calcareous as it approaches the Upper Lias boundary. Both varieties are quarried and are combined in certain proportions before being smelted.

South of the Eastwell workings there is a wide tract of Marlstone in which no quarrying of ironstone is taking place. This is due in part to deterioration of the stone, and in part to the fact that the upper and more ferruginous beds have been much reduced by denudation. Thus, the base of the lower sandy part of the Marlstone is exposed near the surface in the rather shallow cutting along the mineral-railway north of Scalford. But even where the full thickness of Marlstone is present near the Upper Lias of Scalford and Wycomb, no serious attempt to work ironstone has been made, in the opinion that the stone is there too calcareous. If this opinion be justified, it follows that by no means the whole extent of the upper beds of Marlstone still unworked is available as a source of iron ore.

From the Eastwell incline along the mineral tramway of the Staveley Company to its ironstone-workings at White Lodge a general though somewhat variable sequence of the ironstone-beds is recognized, of which the details have been previously stated (p. 45). In this part of the area an average thickness of about 8 ft. of ironstone is obtained. At White Lodge, where the stone passes beneath the Upper Lias, it is worked until the clay 'cover' becomes about 16 ft. thick. Along the S. side of the road to Eastwell, W. of White Lodge, the ironstone fails for a short distance. This 'wash-out,' as it is termed, may be due to a local degeneration of the ore, but is more probably caused by a local rise of the beds bringing up the sandrock.

A series of trial-borings between Eastwell and White Lodge, N. of the present workings, have proved a variable thickness of the ironstone. On the NE. side of the high road, at a short distance before the boundary of the Upper Lias is reached, the ore is relatively thin, probably from the effect of the 'wash-out' mentioned above ; but it recovers its normal thickness of about 12 ft. where it passes under the Upper Lias clay. C. B. W.

The next group of workings begins in the neighbourhood of Holwell on the NE. and stretches practically unbrokenly to Wartnaby on the SW. The

[1] An ammonite, 13 inches in diameter, belonging to the Spinatus group, was obtained from the "Duke's Quarry" in this locality several years ago. This specimen has been recently presented to the Survey collection by Mr. W. Fowler.

operations in this tract are being, or have been, conducted by several companies, including the Stanton Coal & Iron Co., the Holwell Iron Co., and the Bennerley Iron & Coal Co. The same lithological variations prevail as in the tracts previously described, the ore being of the earthy decalcified type on the open plateau, and changing to a more calcareous type as it approaches the covering clay, whether this be the Upper Lias clay, as S. of Holwell, or the boulder-clay, as W. of Wartnaby. The thickness of ore increases somewhat irregularly from its basset edge in the vicinity of the escarpment to about 14 ft. where it passes under the clay. Most of the workings have been mentioned, and one has been particularly described and illustrated in Chapters V and VIII (pp. 47–8, 70–1, Fig. 6 and Pls. I and III), so that no further description is needed here. It requires to be noted, however, that W. of Holwell the conditions are different from those of the areas already dealt with, inasmuch as the ironstone occurs only as a narrowing tongue, practically an outlier, forming the upper part of the Marlstone spur and bounded on both sides, N. & S., by the underlying sandrock of the Marlstone; so that it has no prolongation beneath the Upper Lias save at the eastern commencement of the spur, E. of Holwell. G. W. L.

NORTHAMPTON IRONSTONE.[1]

Although the Middle Lias ironstone is the only ore that has been worked of recent years in the district, the Northampton Sand of the Inferior Oolite, which yields an important ore in Northamptonshire and Rutland, is also a ferriferous rock at its outcrop in the eastern part of the area. Its weathered superficial portion was formerly raised as an ironstone in the neighbourhood of Waltham-on-the-Wolds (p. 57). The rock, though poorer in iron and more siliceous, bears a general resemblance to the Middle Lias ironstone, both in its unweathered and weathered aspects and in the changes it has undergone. Prof. Judd's description of it in its phases and mode of alteration has been quoted above (p. 91). In describing the weathered ironstone in its usual aspect Prof. Judd mentions that "its mass is seen to be made up of two very different materials; that which forms the larger portion of the rock is of a yellowish-brown colour and soft earthy texture; the other portion is of a dark-brown colour, compact, hard, and brittle; the latter contains a considerably larger proportion of iron than the former. The relative distribution of these two materials in the rock is also a feature of very great importance. The hard, brown mineral always occurs in thin plates of from one-third to one-tenth of an inch in thickness; these plates form complete prismatic cells, each of which encloses a mass of light-coloured, earthy mineral, and is itself often surrounded by another layer of the same mineral, never more than one inch thick and usually much less."[2] He further remarks:—"That portion of the bed of ironstone lying nearest to the surface has, in addition to chemical disintegration, usually undergone a certain amount of mechanical denudation, by which means a portion of the soft earthy material is carried away, and the hard laminæ being broken by mutual pressure, the result is a confused mass of irregular fragments of the hard mineral, intermingled with a larger or smaller proportion of the soft mineral. Thus a mass is formed, which of course contains a larger percentage

[1] By C. B Wedd.
[2] "Geology of Rutland, &c." *Mem. Geol. Surv.*, 1875, p. 118.

of iron than the undenuded rock, and it is this portion of the bed which, to the depth of about six feet, is usually dug as an iron-ore. Doubtless, if some ready mechanical means could be contrived for separating the hard layers from the earthy portion of the rock, its value as a source of iron would be greatly increased."[1]

Though in some districts the Northampton Ironstone yields as much as from 30 to 50 per cent. of metallic iron the average quality of the rock raised at Waltham fell considerably below these standards, so that the workings were abandoned; "the analyses varied much, the average showing iron, 20 per cent., silica, 50 per cent., moisture, 10 per cent."[2]

The following analysis of the Northampton Ironstone from Waltham, reproduced from the memoir just cited (p. 120) was made in the laboratory of the Geological Survey, Edinburgh, by Mr. J. S. Grant-Wilson :—

Insoluble in Hydrochloric Acid, 60·97	Silica...	55·01
	Alumina	4·69
	Peroxide of Iron	·17
	Manganese	·21
	Loss in Ignition	·89
Soluble in Hydrochloric Acid, 40·07	Alumina	3·07
	Protoxide of Iron	29·64
	Manganese	·07
	Lime...	trace
	Magnesia	·16
	Phosphoric Acid	·15
	Sulphuric Acid	·05
	Carbonic Acid	1·42
	Water	5·51
		101·04

C.B.W.

GYPSUM.

The deposits of gypsum that occur in the upper part of the Keuper Marl are or have recently been worked at two or three places within the map, but the chief sites of the industry lie slightly beyond its northern and western borders, in Sheets 126[3] and 141. The principal working at present in operation is that of the Snaith Plaster and Cement Co., near the edge of the map, a mile NNE. of Owthorpe, of which a full description has already been given in Chapter III. (p. 15). The gypsum is here obtained chiefly by adits or galleries driven in from the sides of the original open quarry. It occurs at approximately the same stratigraphical horizon as at Newark, not far below the top of the red marls.

The other workings are in the neighbourhood of East Leake, where apparently the gypsum occurs at a somewhat lower horizon, being reached at about 180 ft. below the base of the Rhætic. The

[1] Geology of Rutland, &c." p. 119.

[2] "Geology of the SW. part of Lincolnshire, &c." *Mem. Geol. Surv.*, 1885, p. 47.

[3] "Geology of the Country between Newark and Nottingham." *Mem. Geol. Surv.*, 1908, p. 91.

HYDRAULIC LIMESTONES OF THE LOWER LIAS IN A WORKING ½ MILE E. OF BARROW-UPON-SOAR.
From a photograph, in 1901, by Mr. F. R. Rowley.

present operations are at the W. side of Sharpley Hill, 1 mile N. of East Leake, where it is mined by means of an adit. It was formerly excavated also at Crow Wood Hill and at Hotchley Hill.

The occurrence of gypsum in small exposures at one or the other of these horizons in other parts of the Keuper area has been noticed in Chapter III., pp. 13–15.

The mineral is used principally for the manufacture of fine plasters ('plaster of Paris'); and as a 'filling' material for paper, paint, etc. In the preparation of plaster, the gypsum is carefully calcined and ground, while for other purposes it is ground to an impalpable powder without calcination. The rock is also used to a small extent for decorative purposes and for the manufacture of ornaments. B.S. & R.L.S.

LIME AND CEMENT.

The basal limestones (the 'Hydraulic Limestones' of Chapter IV.) of the Lower Lias are burnt for lime and manufactured into hydraulic cement of noted quality.

This industry is prosecuted on an extensive scale at Barrow-upon Soar, at the SW. corner of the map; and there are other large works at Barnstone, just beyond its N. margin (in Sheet 126), with quarries stretching into the present sheet. A generalized section of the limestone series around Barrow, with some details respecting the workings, has been given in Chapter IV. p. 29, and the Barnstone section was described in the memoir on Sheet 126[1]. The stone is also quarried in the neighbourhood of Owthorpe (p. 26); and there are many small disused pits all along the outcrop, from which, for one purpose or another, it was formerly obtained (*see* Chap. IV. pp. 25–30).

At Barrow the cement industry has a further development in the manufacture of artificial stone and concrete conduits, lintels, paving-slabs, etc.

The limestone is generally obtained by open quarrying; at Barrow it is also drawn from levels driven in for some distance along the course of the beds of approved quality. A photograph of one of the pits at Barrow, illustrating the method of winning the stone, is reproduced in Plate IV.

Lime for building and for agricultural purposes is occasionally prepared from the Lower Lias limestones. The Lincolnshire Limestone (p. 54) of the eastern district was formerly another source of supply, but is now little used.

BUILDING STONE, BRICKS, ETC.

The slabby ('Hydraulic') limestones of the Lower Lias have been used locally for building stone but are neither durable nor pleasing in colour. After they have been subjected to the weather for some time and have partly 'scaled,' they are much tougher, and the best stone is thus prepared. The harder beds of the rock are also raised in large slabs for flagstones which can be obtained up to 6 ft. in length.

[1] "The Geology of, etc., Newark and Nottingham." 1908, p. 64.

The nodular splintery bands at the top of the Rhætic series, along with the tough shelly layers toward the base of the Lias, were formerly much used for road-metalling and are still so used occasionally on the by-roads. But the macadamizing of the mainroads is now mostly done with crystalline rock from Mount Sorrel and Charnwood, and with furnace-slag.

The sandy limestone forming the lower part of the Middle Lias Marlstone ('sandrock') has had a restricted local use in buildings, but is too variable, jointed, and rubbly to yield good building stone.

Bricks have been made here and there, for local supply, from almost all the clayey deposits of the district, mostly in small brickyards many of which are now disused or only occasionally worked. In the large yards at Melton Mowbray (p. 67), Glacial and Alluvial clays are worked. Glacial deposits were also used in the suspended workings at Rotherby (p. 74) and Thrussington. At Stonesby (p. 53) the Upper Lias has been laid under contribution; at Scalford (p. 43), the Middle Lias; at Harby, Upper Broughton (p. 34), Kinoulton (p. 31) and other places, the Lower Lias; and at Quorn and Woodhouse Station, Cotgrave (p. 14), Hoton, Walton (p. 15), etc., the Keuper Marl.

Sand for building purposes is obtained from numerous small pits in the Glacial Sand and Gravel. The sites of most of these have been mentioned in Chapter VIII.

WATER SUPPLY.

Excepting the isolated patches of Glacial Sand and Gravel and the shallow River Gravels, the only readily permeable strata in the district are the Marlstone of the Middle Lias and the Limestone and Sands of the Inferior Oolite. The superficial area and thickness of these formations are too limited to enable them to serve as reservoirs for water on a large scale, but as they rest on impervious strata numerous small springs are thrown out from their bases which are utilized for the water-supply of the houses and villages around their outcrop, and they also generally yield water when wells are sunk into them.

In the Lower Lias tract, the only beds to carry water are the occasional thin bands of limestone and the calcareous sandy belt described on pp. 24 *et seq.* A few small springs ooze from the outcrops of these beds and from the top of the impervious Rhætic Beds, and they also yield a scanty and somewhat precarious supply when tapped in wells.

The thinly inhabited plateau of Boulder Clay has hardly any springs, and its water-supply is gained chiefly from rather deep wells which usually find a little water in the streaky and less compact lower portion of the deposit, or in the sandy or gravelly lenticles which occur here and there within the mass.

In the Keuper Marl area, most of the water is obtained from shallow wells in the thin patches of drift and alluvium overlying the Marl.

The public water-supply of Melton Mowbray is drawn chiefly from springs issuing from the base of the Marlstone in the branching valleys N. of Scalford. It is subject to seasonal variation, a continuous gauging from January to July, 1902, giving a maximum of 110,156 gallons for 24 hours on March 17th and a minimum of 38,322 gallons on July 26th.[1] A further supply is obtained from an older reservoir on the W. side of the Scalford valley, where the Marlstone outcrop is hidden under the edge of the boulder-clay.

AGRICULTURAL GEOLOGY.

The map embraces a rich and fertile country in which there is practically no waste land, and little woodland excepting in the planted grounds of Belvoir Castle and a few other park-lands. Owing to the preponderance of stiff clay-soils the proportion of pasture to arable land is high in most parts of the district; consequently stock-raising and dairy-farming assume great importance throughout the district, and the Vale of Belvoir has a considerable cheese-making industry. To the same factor is due the wide repute of the tract as a field for fox-hunting. The only light soils are those on the Marlstone of the Middle Lias; on the Sands and Limestone of the Inferior Oolite; and on the scattered patches of Glacial Sand and Gravel, and River Gravels.

While the survey of the area was in progress an investigation into the soils of part of the ground and their relation to the geology was carried out by Mr. A. D. Hall of Rothamsted and Prof. T. H. Middleton, and will be referred to further subsequently. The geological boundaries conform fairly well to the varied character of the soils and subsoils, though the margins of the superficial deposits are rarely so sharply defined as the lines necessarily drawn for their delimitation on the map might seem to imply. Also, on steep slopes there is generally more or less downwash of material, often crossing the geological boundaries and altering or modifying the soil, which the geologist is compelled to leave out of account in tracing the stratigraphical lines. Similarly, on the lowland tracts there are irregular patches of drift and other superficial detritus too small and indefinite to be shown on the map, yet sufficient to have much effect upon the soil; but in most of the tracts thus affected, it has been found possible to call attention to the fact by words printed on the map.

The lowland of Keuper Marl is especially modified by the last-mentioned condition, so that the soil covering its outcrop in this map is frequently a brownish pebbly loam instead of the stiff red clay usual on this formation.

The following analyses of the unweathered Marl from parts of the outcrop in Sheet 126, slightly north of the present map, made in the Chemical Laboratory of the Survey under the superintendence of Dr. W. Pollard, are inserted here as illustrating the composition of the deposit.

[1] We are indebted to Mr. Baldwin Latham, M.I.C.E., for this information.

Analyses of Keuper Marls.

288. Red Keuper Marl, Mapperley, Nottingham.
289. Tea-green Marl, Beacon Hill Quarry, Newark.
290. Red Keuper Marl. From the Vale of Belvoir and Newark Plaster Co's Quarry, Bowbridge, near Newark.

Bulk Analysis.

	288.	289.	290.
SiO_2	54·95	47·36	52·37
TiO_2	·65	·60	·66
Al_2O_3	15·54	15·05	13·72
Fe_2O_3	3·27	2·71	4·04
FeO	1·43	1·94	1·37
MnO	trace.	trace.	trace.
(CoNi)O...	nt. fd.	nt. fd.	trace.
CaO	3·78	5·90	5·09
MgO	5·11	6·24	5·92
K_2O	4·29	4·19	3·65
Na_2O	·37	·61	·86
Li_2O	trace.	trace.	trace.
H_2O @ 105° C.	2·80	2·21	1·87
H_2O above 105° C.	3·48	3·79	3·27
P_2O_5	·15	·12	·10
FeS_2	·09	1·27	·07
SO_3	·06	·17	·12
CO_2	4·30	8·55	7·49
Total	100·27	100·71	100·68

(Analyst, E. G. Radley.)

Lime and magnesia soluble in hydrochloric acid :—(method as advised by Soil Analysis Committee : A. D. Hall, 'The Analyst,' 1900, p. 281.)

	288.	289.	290.
CaO	3·76	5·94	5·14
MgO	2·75	5·29	4·26
SO_3	·06	·17	·12

SiO_2 from silicates decomposed by hydrochloric acid and dissolved by soda :—

12·90	16·16	12·12

SiO_2 decomposed from silicates in residue from above by sulphuric acid and dissolved by soda :—

8·62	10·20	10·86

Sand and acid silicates undecomposed by either sulphuric or hydrochloric acids :—

37·63	22·57	31·97

W. Pollard.

The outcrop of the Rhætic carries a brown clay soil, but is too narrow to be of much agricultural consequence. The following two analyses of the marls near the top of the formation, for which we are indebted to Mr. J. Ward, of the Barnstone Blue Lias Lime Co., illustrate the composition of this portion of the series.

Analyses of 'White Lias' marls from Barnstone.

	No. 1.	No. 2.
Ferrous Oxide	3·57	4·01
Alumina...	13·84	12·34
Lime	14·50	15·40
Magnesia	3·14	4·39
Silica	38·20	35·80
Sulphuric acid	·08	·14
Moisture	3·56	4·86
Carbonic acid and combined water	23·11	23·06
	100·00	100·00

The outcrop of the Lower Lias, on which the Vale of Belvoir is situated, produces a heavy clay soil of dark colour. This land is modified and rendered more fertile along definite belts by the bands of limestone interbedded with the shaly clays, and also by the presence of shallow pockets of gravelly or sandy drift. It affords grass of excellent quality, and in this tract the grazing land predominates greatly over the area under the plough. Calcareous matter, though variable in amount, is generally present in the clays.

Some partial analyses of the soils of the district made at Rothamsted under the superintendence of Mr. A. D. Hall, in connexion with the investigation mentioned above, included the following from the Lower and Middle Lias clay-tract.

Lower Lias Soils.

Sample Number.	Locality.	"Fine Gravel" (retained by 1 mm. sieve).	"Coarse Sand" (retained by ·2mm. sieve).	Carbonates expressed as $CaCO_3$
		%	%	%
1	Stathern, 650 yds. ESE. of Church (near edge of drift)...	2·21	8·19	2·33
3	Stathern, 600 yds. S. of Church (near edge of drift)	1·34	11·26	1·64
5	Stathern, about 1 mile N. of village (above thin limestones)	·81	15·28	1·94
6	Stathern, yellow soil at foot of Belvoir escarpment	·50	7·58	1·71
	Middle Lias Clay Soil.			
8	Old Dalby, ridge NE. of tunnel, 300 yds. N. of tram-line ...	2·31	3·50	1·61

The clayey lower division of the Middle Lias, so far as its agricultural characters are concerned is inseparable from the Lower Lias clays with which it is conterminous. As, however, its narrow outcrop in the district almost everywhere occupies the lower slope of the great Marlstone escarpment, its surface is frequently modified by sandy ferruginous downwash, but the ground is often too steep and uneven for successful cultivation.

The Marlstone plateau has a light loamy soil, generally rusty-brown in colour and full of rubbly fragments of ironstone. Being easily tilled and fertile, there is a much larger proportion of ploughed land in this tract than in any other part of the map. Owing to its permeability and consequent thorough decalcification this soil is deficient in lime. As already mentioned (p. 92), the working of the ironstone is so arranged as to interfere as little as possible with the agricultural operations; large areas have thus been quarried over and are now again under crops.

The Upper Lias forms a heavy dark clay soil, very similar to that of the Lower Lias; the Northampton Beds support variable soils, predominantly light and sandy, and occasionally ferruginous; and the Lincolnshire Limestone has a rich calcareous loam which is mostly under the plough; but the area covered by these divisions is comparatively small.

The soils derived from the Boulder Clay are usually stiff brownish clays, not quite so tough and 'sad' as those of the Lower Lias, but showing a wide range of variability in texture, colour and mineral composition corresponding to the irregular and locally changing proportions of the different materials in the boulder-clay itself (Fig. 9, p. 79). Thus, in places where chalk or oolitic limestone detritus is particularly abundant, as in the belt between Waltham and Sysonby (p. 68), the soil is calcareous and somewhat loamy; while in places where Liassic detritus predominates, it is heavy and often decalcified by weathering. The varying proportion of the stony ingredients has also much effect upon the character of the boulder-clay soils which sometimes become quite gravelly. Indeed there is often a gradual passage from the boulder-clays to the sandy gravels of the Glacial series, and therefore from a stiff clay-soil to a light sandy soil; so that their boundaries are rarely well-defined agriculturally. As a whole, however, the tracts coloured on the map as Boulder Clay are strong land, and the tracts shown as Glacial Sand and Gravel are light land.

The following partial analyses of drift-soils from the neighbourhood of Stathern and Old Dalby were made in the Rothamsted Laboratory:—

Drift Soils.

Sample Number.	Locality.	"Fine Gravel" (retained by 1 mm. sieve).	"Coarse Sand" (retained by ·2mm. sieve).	Carbonates expressed as $CaCO_3$
		%	%	%
2	Stathern, 600 yds. ESE. of Church	4·94	12.60	10·38
4	Stathern, 780 yds. S. of Church...	2·06	8·58	4·68
9	Old Dalby, ridge NE. of tunnel, 200 yds. N. of tram-line ...	·53	7·42	1·66
10	Old Dalby, ridge NE. of tunnel, 150 yds. N. of tram-line ...	·16	4·05	1·29
11	Old Dalby, ridge NE. of tunnel, near pond, 350 yds. ESE. of No. 10...	·26	4·52	1·43

In the smaller valleys near Barrow-upon-Soar the deposits classed with the "Older River Gravel" are frequently rendered clayey by the quantity of material washed from the adjacent clay-slopes (p. 85). Elsewhere this division and the newer "River Gravel" form stony-loam soils.

The composition of the Alluvium of the river-flats varies in accordance with that of the drainage-basins of the streams, as described in Chapter IX. Clayey-loam soils predominate, with some gravelly land in the valleys of the Soar and Wreak. Being low-lying and often wet, these tracts are chiefly meadow-lands. Peaty soils prevail in the broad shallow basin forming the 'moors' west of Bunny (p. 88), and being easily tilled a large proportion of this tract is under the plough. G. W. L.

APPENDIX I.

Some Important Borings and Sinkings.

Owthorpe.

Boring for Coal.

1 in. map (N.S.) 142. 6 in. map, Notts. 47 NW.

Height above O.D. 200 ft.

Abridged from fuller account given in the "Geology of Newark and Nottingham." *Mem. Geol. Surv.*, 1908, pp. 106–8, and "Geology of S.W. part of Lincolnshire." *Mem. Geol. Surv.* 1885, p. 150–2.

			Thickness. Ft.	In.	Depth. Ft.	In.
Lower Lias	Clays and limestones		12	6	12	6
Trias	Rhætic 34 ft. 6 in.	Blue shale	1	3		
		Grey marl	19	3	33	0
		Black shale	14	0	47	0
	Keuper Marl 627 ft.	Blue stone and clay [Tea-green Marl]	19	0	66	0
		Red marls with partings of hard grey and blue rock, blue marl, and beds or veins of gypsum	608	0	674	0
	Keuper Waterstones 121 ft.	Hard red and grey rock ...	20	0		
		Hard red sandstone	49	0	743	0
		Red and grey rock mixed with marl	30	0		
		Bluish grey rock	22	6	795	6
	Bunter Pebble Beds 274 ft.	Red and grey sandstone ...	7	0		
		Red and grey sandstone with pebbles	139	6		
		Stiff red clay...	2	0	944	0
		Red and grey sandstone with pebbles	56	0	1000	0
		Red and grey sandstone ...	50	0		
		Conglomerate sandstone ...	19	0	1069	0
Coal Measures 963 ft. 3 ins.	Red marl, shales and ironstone, with a 3 in. bed of coal		76	6		
	Coal		2	4	1147	10
	Shales, sandstones, ironstone and conglomerate		152	2		
	Coal		2	3	1302	3
	Shales, fire clays, ironstones, &c., with 5 coal seams, from 3 ins. to 22 ins. thick		198	11		
	Coal		3	3	1504	5
	Shales, fireclays, sandstones, ironstones (including Marine Bed), &c., with 5 coal seams from 5 ins. to 15 ins. thick		222	1		
	Coal		3	5	1729	11
	Fireclays and ironstone		24	2		
	Coal		2	9	1756	10
	Shales, fireclays, sandstone and ironstones with 4 coal seams from 5 ins. to 14 ins. thick ...		59	2		
	Coal		3	6	1819	6
	Fireclays and ironstone		15	4		
	Coal		1	6	1836	4
	Grey shale with sandstones		29	1		
	Coal		2	9	1868	2
	Shale, fireclay and ironstone		8	2		

Coal Measures *cont.*	Coal	1	5	1877	9
	Shales and ironstone	41	2		
	Coal	2	8	1921	7
	Shale, ironstone and sandstone	22	2		
	Bluish grey rock with spar joints (Igneous Rock)	39	1	1982	10
	Shale, sandstone and limestone	24	10		
	Coal	4	8	2012	4
	Fireclay, shales and sandstones	19	11	2032	3

Ruddington.

BORING FOR COAL.

1 in. map (N.S.) 142. 6 in. map, Notts. 46 NW.

Height above O.D. 100 ft.

Abridged from account given in "Geology of Newark and Nottingham." *Mem. Geol. Surv.*, 1908, pp. 112–113.

			Thickness. Ft.	In.	Depth. Ft.	In.
		Soil	1	0		
Glacial		Sand and gravel	2	0		
		Clay, sand and gravel	4	0	7	0
Trias	Keuper Marl 386 ft.	Red and blue marl with thin beds of soft sandstone or limestone and gypsum veins	386	0	393	0
	Keuper Waterstones 73 ft. 9 in	Red and grey sandstones, marls, and marly sandstones	70	9		
		Conglomerate...	3	0	466	9
	Bunter Pebble Beds 220 ft. 7 in.	Red and grey pebbly sandstones with partings of red and blue marl	218	7		
		Coarse red sandstones with grey veins	2	0	687	4
Coal Measures	Lower Coal Measures 443 ft. 8 in.	Red and grey sandstones with beds of marl	11	8	699	0
		Red and grey sandstone with thin beds of blue shale [Wingfield Sandstones?]	58	9	757	9
		Shales, fireclays and ironstones (thin veins of coal near face)	184	4		
		Coal, Naughton	2	5	944	6
		Clay with ironstone and shale	21	6		
		Coal	1	0	967	0
		Fireclay, shale, and shaly sandstone	49	8		
		Blue shale with ironstone bands [Marine Bed] ...	52	9		
		Coal, Alton	3	4	1072	9
		Fireclay and shales	32	1		
		Coal	0	7	1105	5
		Shale with coal partings, sandy shale and shaly sandstone ...	25	7	1131	0
Millstone Grit Series 739 ft. 4 in.		Grey sandstone, in places pebbly and shaly [Rough Rock]	164	8	1295	8
		Blue shale with ironstone	67	1		
		Blue shale [Marine Bed—*Lingula squamiformis*]	7	2	1369	11
		Sandstone, shale and ironstone bands	50	7		
		Coal	0	3	1420	9
		Fireclay, sandy	8	0		

		Thickness. Ft.	In.	Depth. Ft.	In.
Millstone Grit Series—*cont.*	Grey sandstone and stone bind	111	3	1539	0
	Blue shale, shaly sandstone, ironstone and thin veins of coal	218	3		
	Coal	1	4	1758	7
	Fireclay	0	8		
	Coal	1	4	1760	7
	Fireclay	0	4		
	Blue shaly and grey and reddish sandstone [Kinderscout Grit]	109	5	1870	4

Holwell Iron Works.

Boring for Water, 200 yards E. of Holwell New Ironworks, Asfordby Hill.

1 in. map (N.S.) 142. 6 in. map, Leicester 19 NE.

Height above O.D. about 320 ft.

Communicated by the Holwell Iron Company.

		Thickness. Ft.	In.	Depth. Ft.	In.
Glacial	Yellow clay, easily got	10	0		
	Yellow clay with blue cast	77	0		
	Sandy loam	2	0		
	Blue clay with very much gravel	8	6	97	6
Lower Lias 27 ft. 9 in.	Brassy rock	0	1½		
	Blue clay—very soft shale	5	0		
	Hard white rock [Limestone band]	0	4		
	Blue shale	0	8		
	Brassy rock	0	1½		
	Blue shale—medium strength, with small fossils	9	3	113	0
	Blue clay—stained with ochre	0	3		
	Dark blue bind	3	0		
	Mass of fossils in white rock heavily stained with ochre [? Limestone band]	0	4	116	7
	Blue shale	3	5		
	Blue shale—excess fossils	0	8		
	Blue shale	4	7	125	3

Water burst in, and rose 40 ft. in well.
Strata dip at about 1 in 24 toward east.

Melton Mowbray.

Boring for Water, about 200 yards W. of the Great Northern Station, Melton.

1 in. map (N.S.) 142. 6 in. map, Leicester 20 NW.

Height above O.D. about 260 ft.

Abridged from the account published in "Geology of SW. part of Lincolnshire, &c." *Mem. Geol. Surv.*, 1885, pp. 147–8.

Communicated by Messrs. Legrand and Sutcliff.

		Thickness. Ft.	In.	Depth. Ft.	In.
	Soil	2	0		
Post-glacial ?	Loam, clay, sand and gravel	12	0	14	0
Glacial ...	Blue clay and stones [Boulder Clay] ...	24	0	38	0
Lower Lias ...	Blue clay, shale and stone	230	8	268	8
Rhætic ...	Dark shaly clay and stone	16	4	285	0
Keuper Marl	Grey marl and stone [Tea-green Marl] ...	24	0	309	4
	Red marl, with beds of grey marl, grey sandstone and gypsum	223	10	532	10

Saxby.

BORING FOR WATER, about 560 yards S10°E. of Saxby Church.
1 in. map (N.S.) 142. 6 in. map, Leicester 20 NE.
Height above O.D. about 290 ft.

Communicated in 1891 by the Trustees of the late Earl of Dysart; (published also in "Geology of the Country near Leicester." *Mem. Geol. Surv.*, 1903, p. 94).

		Thickness. Ft.	In.	Depth. Ft.	In.
	Soil and blue clay	14	0		
LOWER LIAS	Nodular limestone rock	2	6	16	6
	Blue clay	31	0		
	Rock	2	0		
	Blue clay	76	0		
	Rock (small supply of water from this rock)	7	6	133	0
	Clay	92	0		
	Rock (water found here)	4	6	229	6
	Clay and soft rock)	2	0		
	Rock	8	6		
	Clay	36	6		
	Rock (a little more water found in this rock)	5	0	281	6
	Clay	16	6		
	Rock	4	0		
	Clay	7	6	309	6

Scalford.

SHAFTS AND BORINGS AT THE MELTON MOWBRAY WATER-WORKS.
1 in. map (N.S.) 142. 6 in. map, Leicester 13 NW.
Communicated by Mr. Baldwin Latham, M.I.C.E.

Numerous shallow shafts were sunk at distances from ½ mile to 1 mile N. of Scalford. These shafts are situated, some above, some just below the base of the Marlstone. As they traverse approximately the same strata, the following will suffice as illustrations :—

Section at Ram-chamber A ; 920 yards N14°E. of Scalford Church.
Height above O.D. 393·83 ft.

			Depth. Ft.	In.
	Surface soil		1	0
MIDDLE LIAS.	Marlstone ...	Loam ... ... [to]	4	0
		Soft sandstone with little iron and clay	4	9
		Soft sandstone in thin layers ... [to]	7	0
		Nodules of grey limestone with some iron ... ... [at]	14	6
		Soft sandstone in thin layers ... [to]	15	6
		(Water met with at	21	0)
		Soft sandstone with some hard lumps of ironstone and a little clay ... [to]	22	0
		Grey marl ... ... „	23	0

Section at Shaft E ; 1550 yards N18°E. of Scalford Church.
Height above O.D. 402·6 ft.

			Depth. Ft.	In.
	Surface soil		2	0
MIDDLE LIAS CLAYS.	Loam	[to]	5	0
	Clay	„	6	6
	Sandy shale	„	11	6
	Blue marl	„	15	10

Records of shallow well-sections at Asfordby, Kirby Bellars, Seagrave, Hoby and Frisby, may be found in "Geology of the Country near Leicester." *Mem. Geol. Surv.*, 1903, pp. 89–91.

Well-sections at the following places are also mentioned in the text of the present memoir :—Canal Farm, near Hickling (p. 31), Eastwell (p. 72), Keyworth (p. 80), Langar (p. 31), Lion Brickworks, near Scalford (p. 43), Scalford and neighbourhood (pp. 44, 46. 52), South Lodge, near Widmerpool (p. 31), Stanford Park (p. 81), Stapleford Park (p. 38), Sysonby House (p. 66), Waltham and neighbourhood (pp. 58, 60), Wycomb (p. 43), and Wysall (p. 81).

APPENDIX II.

List of some Works on the Geology of the District.

1852. Egerton, Sir P. de M. G.—British Organic Remains. *Mem. Geol. Surv.*, dec. vi., pl. vii. [*Ptycholepis minor* from Barrow-on-Soar]; also *op. cit.*, dec. viii., pl. x., 1855 [*Pycnodus liassicus*]; and *op. cit.*, dec. ix., pl. i., 1858 [*Cosmolepis gen. nov.*].

1855. Hull, E.—1-in. Geological Map, Old Series, Quarter-sheet 71 SE. *Geol. Surv.* 2nd ed., with additions by W. T. Aveline, in 1879.

1857. Brodie, Rev. P. B.—Remarks on the Lias of Barrow in Leicestershire, compared with the lower part of that formation in Gloucestershire, Worcestershire and Warwickshire. *Proc. Cotteswold Field Club*, vol. ii., 1860, pp. 139–141. See also *Rep. Brit. Assoc.* for 1866, Trans. of Secs., p. 51.

1858. Aveline, W. T., E. Hull, and T. R. Polwhele.—1-in. Geological Map, O.S., Quarter-sheet 71NE. *Geol. Surv.* 2nd ed., with additions by W. T. Aveline in 1879.

—— Howell, H. H.—Horizontal Section. Sheet 46. No. 2, Nailstone to Barrow-on-Soar. *Geol. Surv.*

1866. Hull, E.—The new Iron-fields of England. *Quart. Journ. Sci.*, vol. iii., pp. 323–332.

1874. Irving, Rev. A.—On the Geology of the Nottingham District. *Geol. Mag.*, dec. ii., vol. i., pp. 317–8; also more fully in *Proc. Geol. Assoc.*, vol. iv., 1875, pp. 69–84.

1875. Judd J. W.—The Geology of Rutland, and the parts of Lincoln, Leicester, etc. [Sheet 64, Old Series]. *Mem. Geol. Surv.*

1882. Harrison, W. J.—Geology of Nottinghamshire, No. 28 in *Geology of the Counties of England and . . . Wales*, pp. 207–11. Lond.

—— Wilson, E.—On the Rhætics of Nottinghamshire. *Quart. Journ. Geol. Soc.*, vol. xxxviii., pp. 451–456; also see *Rep. Brit. Assoc.* for 1881, and *Mid. Nat.*, vol. vi., pp. 193–9.

1885. Jukes-Browne, A. J. and W. H. Dalton.—The Geology of the South-west part of Lincolnshire, with parts of Leicestershire and Nottinghamshire. (Sheet 70) [O.S.]. *Mem. Geol. Surv.*

—— Wilson, E.—The Lias Marlstone of Leicestershire as a source of Iron. *Mid. Nat.*, vol. viii. With map, pp. 61–6, 94–7, 123–7, 152–8.

1886. Deeley, R. M.—The Pleistocene Succession in the Trent Basin. *Quart. Journ. Geol. Soc.*, vol. xlii., pp. 437–480.

—— Holloway, W. H., and others.—1-in. Geological Map, Old Series, Sheet 70 (in two editions: 'Solid' and 'Drift'). *Geol. Surv.*

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